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A TREATISE ON THE

PROGRESSIVE IMPROVEMENT & PRESENT STATE

OF THE

MANUFACTURES IN METAL.

VOL. I.

J. Holland

IRON AND STEEL.

NEW EDITION

REVISED BY ROBERT HUNT,

Professor of Mechanical Science, Government School of Mines.

1853.

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NOTICE.

In the revision of the present volume, the principle has been adopted of retaining unchanged all such portions of the original matter as correctly describe the existing conditions of Iron and Steel Manufacture.

In each section of the work, many additions have been made, so as to complete the practical and statistical information up to the date of publication.

To several Iron Masters and Steel Manufacturers, who have furnished much valuable matter, I must tender my especial thanks.

R. H.

July 30th, 1853.

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A
TREATISE
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MANUFACTURES IN METAL.

IRON AND STEEL.

CHAPTER I.

INTRODUCTION.

EXISTENCE OF METALS. — EARLY TRACES OF THEIR PRESENCE. — ACCIDENTAL CAUSES OF FUSION. — FIRST METALLURGISTS. — COPPER, IRON, AND STEEL. — DISCOVERIES OF NATIVE AND METEORIC MASSES. — IRON AND STEEL, WHETHER KNOWN TO THE HEBREWS, GREEKS, AND ROMANS. — ANCIENT METHODS OF PREPARING STEEL.

ALTHOUGH the globe on which we live exhibits but few traces of metallic veins at its surface, we have strong evidence for believing, that in the earliest stages of that semi-civilisation which appeared amongst the nomadic races of mankind, several metals were rendered available for use and ornament.

It is useless now to speculate on the accidents which led man to a knowledge of the effects of fire in producing the separation of the pure metals from their ores: it may not, however, be without its use to examine the probable natural conditions of those metals which were probably the first employed by man.

The surfaces of mountains and cliffs, which had suffered disintegration from the atmospheric changes to which they were exposed, or had undergone extensive denudation by the long continued action, during geological ages, of ocean currents, must have given the earliest indications of mineral formations. The beds of torrents which during the winter seasons swept the debris from the mountains, being left dry during the summer heats, must have exposed many of the metallic minerals. These were doubtless first used amongst men — while those which were situated deep in the earth could not have been wrought, until necessity, by taxing the inventive powers of the human race, had taught mankind the mechanics required in even the most simple operations of mining.

In the rivers of the East, along the banks of which human industry must have been first exerted, gold was discovered in deposits similar to those which are now attracting so much attention in California and Australia. Over the same regions, the ores of iron are extensively distributed, the massive peroxides of iron forming large portions of several mountain ranges, while the magnetic oxide of iron is spread as sand over widely extended districts. The rude Indian bellows, which is now employed by the native Hindostanee, formed from the stumps of trees, and used as a kind of pump, a piston being fitted to the hollow, is in all probability a representation of the most primitive form employed for producing the heat necessary to fuse the refractory ores of iron. These two metals, there is every reason for supposing, were employed by man long previously to the discovery of any other metalliferous minerals.

Mineralogists have started the question — long an involved one — whether all the mineral treasures which have been extracted from, and those at present existing in, the bowels of the earth, were formed, like the materials amidst which they mostly lie, at the creation, or whether they may not have been the production of subsequent periods, either resulting from some of those singular phenomena which are obviously attributable to violent physical operations, or from chemical changes perpetually going on, according to fixed laws, throughout all the regions of nature with which we are acquainted? The discussion of this subject, interesting as it is, belongs, however, rather to geology and chemistry than to the arts of working in metal. A passing allusion to it, therefore, may suffice in this place.

With respect to the existence of gold as a primary element of our globe, we appear to have the affirmative testimony of Moses in the second chapter of Genesis, where, mentioning the situation of Eden, he likewise describes the four heads of the rivers by which the garden was watered, and says, — "The name of the first was Pison: that is it which compasseth the whole land of Havilah, where there is gold; and the gold of that land is good." This is certainly the earliest instance on record in which mention is made of the existence of any metal; but although commentators do not dispute the propriety of the translation in this place, it may be contended, that the sacred historian may refer to the rivers as they are presumed to have been known at the time when he wrote, rather than as they might have existed at the formation of Eden. Be this as it may, there can be no doubt that the locality anciently assigned to the waters in question, possesses a sufficient degree of geographical identity with that part of the world where gold is at present and has always been found, to justify these remarks.

The presence of many metals must, in the earliest times, have become, in various ways, too obvious to allow the art of smelting their ores to have remained long undiscovered. The detection of the native metal, or the accidental effect of fires upon the more fusible ores, are circumstances which account at once for the early notions and strange fictions which existed among the ancients on this subject; especially the natural and poetical idea of the conflagration of a forest by the rubbing of trees against one another during a high wind, and the consequent fluxion of some of the metal from ores lying exposed on or near the surface.

Bishop Watson, in his Chemical Essays, pertinently observes, that "the earth, in a little time after the deluge, and long before it could have been peopled by the posterity of Noah, must have become covered with wood. The most obvious method of clearing a country of its wood is setting it on fire; now, in the most mineral countries, there are veins of metallic ores, which come up to the surface of the earth, and these having been fused whilst the woods growing over them were on fire, probably suggested to many nations the first idea of smelting ores:—

> ——'Powerful gold first raised his head,
> And brass, and silver, and ignoble lead:
> When shady woods on lofty mountains grown,
> Felt scorching fires; whether from thunder thrown,
> Or else by man's design the flames arose,—
> Whatever 'twas that gave these flames their birth,
> Which burnt the towering trees and scorched the earth;
> Hot streams of silver, gold and lead, and brass,
> As nature gave a hollow proper place,
> Descended down and formed a glittering mass.'

"There is no natural absurdity in this notion of the poet; and, indeed, it is confirmed by the testimony of various ancient historians, who speak of silver and other metals being melted out of the earth during the burning of the woods upon the Alps and the Pyrenees. A similar circumstance is said to have happened at Croatia, in the year 1762: a large mass of mixed metal, composed of copper, iron, tin, and silver, having been fluxed during the conflagration of a wood which was accidentally set on fire."

This consistent hypothesis, which has been adopted by the old French poet Du Bartas, comes out even in the verbose translation of Joshua Sylvester, with a force and brilliancy like the issuing of molten iron from the furnace:—

> "While through a forest *Tubal* (with his yew
> And ready quiver) did a boar pursue,
> A burning mountain from his fiery vein,
> An yron river rowles along the plain.
> The witty huntsman musing thither hies,
> And of the wonder deeply 'gan devise.
> And first perceiving that this scalding metal,
> Becoming cold, in any shape would settle,
> And grow so hard that with his sharpened side
> The firmest substance it would soon divide;
> He casts a hundred plots and yer he parts,
> He moulds the groundwork of a hundred arts."

It would be tedious to allude to the various fables in which the ancients have endeavoured to immortalise those who have benefited the world, by inventing or extending the methods of working in metals. We cannot lay much stress upon the supposed antiquity of certain arts from the Scripture notice of Tubal Cain, the antediluvian "instructor of every artificer in brass and iron." On this point we may, however, again quote Bishop Watson's remarks, who, referring to the history of the human race in the book of Genesis, says, "It is somewhat remarkable that from this account, short as it is, the chemists should be authorised, with some propriety, to exalt the antiquity of their art to the earliest times. Tubal Cain is there mentioned as an instructor of every artificer in copper and iron. This circumstance proves, beyond dispute, that one part of metallurgic chemistry was well understood at that time, for copper and iron are, of all the metals, extracted from their ores with the most difficulty, and cannot, even in our days, be rendered malleable without much skill and trouble; and it proves, also, that the arts in general were in an improved state amongst the antediluvians. It is said, indeed, that some tribes of Hottentots (who can have no pretensions to be ranked amongst the cultivators of the arts) know how to melt both iron and copper; but this knowledge of theirs, if they have not derived it from an intercourse with the Europeans, is a very extraordinary circumstance, since the melting and manufacturing of metals are justly considered, in general, as indications of a more advanced state of civilisation than the Hottentots have yet arrived at. Still less can we derive any information from the fabulous credit attached by the mythologist to the discoveries of Ithonus, the son of the Thracian Noah, whom the Greeks accounted to have found out the fusion of the metals, and the art of coining money. It is, however, probable enough that as in Tubal's time the inhabitants of the earth had not only built cities, but were possessed of sufficient ingenuity to construct so vast a vessel as the ark, that many handicraft arts may have been practised and taught by the son of Zillah, and have existed extensively before the flood.

Gold and silver, as being of most obvious occurrence in those parts of the world which were earliest peopled, would, no doubt, be among those first submitted to manufacture; rather, however, for the purposes of ornamenting the persons of the finders, than either for utensils of convenience, implements of ingenuity, or weapons of defence. It is, indeed, remarkable at how early a period, and how generally, a knowledge of the value as well as the ductility of the precious metal appears to have obtained in the world; the most barbarous nations instinctively decorating themselves with ornaments of gold and silver. It must be apparent to every one how unfit instruments of these metals must be either for tools or arms, compared with others of the more common class. Hence it is, that in countries where gold or silver have neither been unknown nor scarce, the natives who have worn rings of these metals on their limbs, have resorted to pointed bones or sharpened flints for their bodkins or their war spears: a nail or any piece of iron being to them of more value than their softer precious metals.

The hardening of copper by the admixture of tin, seems to have been introduced at a very early period into the manufactures of semi-civilised nations, and is generally to be understood when the terms *brass* or *brazen* occur in authors; brass properly being a factitious metal. For the extensive prevalence of some hard and useful metal, in very early times, we have the direct testimony of historians: brazen swords, brazen spears, brazen shields; brazen ploughshares, brazen helmets, brazen statues, and a long *et cetera* of other articles, are perpetually occurring in the pages of ancient authors. To these may be added the numerous antiquities deposited in the different museums of Europe; and even such are yet occasionally turned up by the spade or the ploughshare, in those situations where they have been dropped by the aborigines or their invaders. A more particular account of the composition of the metal of these vestigia will be given in a future page; they are all, however, true bronzes, that is, mixtures of copper and tin.

Of iron and steel — metals so pre-eminently valuable in the artificery of modern times, the early races of mankind appear to have possessed *but a very imperfect* acquaintance. This may have been owing partly to the geographical situations in which the ore is generally found, and partly to the fact of native masses being extremely rare; but mainly, it is to be presumed, to the obdurate nature of the ironstone itself, which can only be brought into a state of fusion by the most intense heat in a furnace, from which it flows in masses too intractable for reduction without tolerable implements, and some considerable knowledge of metallurgy. Besides, however, the difficulty of fusion, another objection has been urged against the use of iron among uncivilised nations, namely, that allowing the iron ore to be reduced, the metal thus formed would not be malleable, but cast iron, and consequently incapable of being applied to useful purposes by a people void of mechanic combinations, and without the aid of powerful machinery. It may be sufficient in this place to adduce in reply to the foregoing remark, the fact that malleable iron preceded the use of such machinery; for all the machines of which we have any certain knowledge, that are used for the making of iron malleable, are themselves made of iron; and it must be allowed that the material was known before the utensil could be formed.

The existence of pure native iron was formerly questioned; of the fact, however, that such pieces have been found there now remains little doubt. At the mines of Kamsdorf and Eibestoch in Saxony, native iron has been found forming the centres of stalactiform masses of brown hematite, and a similar phenomenon has been observed in the mountains of Oulle near Grenoble. This native metal is not exactly like ordinary iron; it is whiter and more ductile, and there is little doubt but it has been produced by the decomposition of a chemical compound of iron with, probably, sulphur. More recently it has been found in three places in the United States, at Canaan in Connecticut, Pennsylvania, and North Carolina. In neither case was the iron perfectly pure, copper, lead, carbon, and arsenic being found in the different specimens. A mass of malleable iron, which from its composition appears to have been of meteoric origin, weighing 1680 Russian pounds, was found in Siberia in 1752. It was easily cut with chisels, and in many places presented cavities filled with small polished pieces of hyacinthine spar.

The discovery of pieces of meteoric iron has not been confined to the old world. In the "Philosophical Transactions" (1788), there is a paper on the finding of a mass of native iron in South America, in 1783, by Don Michael Rubin de Ceslis, a Spaniard. The block, which was three yards across, and weighed 300 quintals, was found at Otumba, almost buried in pure clay and ashes. The notice is curious:—"The exterior appearance of it was that of perfectly compact iron; but on cutting off pieces of it (says the narrator), I found the internal part full of cavities, as if the whole had been formerly in a liquid state. I was confirmed in this idea by observing on the surface of it the impressions as of human feet and hands of a large size, as well as the feet of large birds, which are common in this country. Though these impressions seem very perfect, yet I am persuaded that they are either a *lusus naturæ*, or that impressions of this nature were previously on the ground, and that the liquid mass of iron falling on it received them. It resembled nothing so much as a mass of dough, which, having been stamped with the impressions of hands and feet, and marked with a finger, was afterwards converted into iron." This mass was found to be very soft metallic iron, easily cut with a chisel, and capable of being wrought without difficulty on the anvil when heated.

That stones have fallen from the clouds, as well in England as elsewhere, seems to be a fact placed beyond all reasonable doubt in the annals of philosophy. The chemical constitution of these masses appears to have been pretty uniform in the various specimens which have been examined. They all contained an alloy of iron and nickel with cromium, and have a peculiar black silicious coating, which varies but slightly in composition.

These important facts were first determined by the Hon. Mr. Howard, who collected specimens of stones which had fallen at different times, procured as much information as possible respecting them, compared the physical or exterior characters of these bodies, and even did more, in subjecting them to chemical analysis by means as ingenious as exact. "It results," says Vauquelin, "from his researches, that the stones which fell in England, in Italy, in Germany, in the East Indies, and in other places, have all such a perfect resemblance, that it is almost impossible to distinguish them from each other; and what renders the similitude the more perfect and more striking is, that they are composed of the same principles and nearly in the same proportions."

Mr. Howard's memoir, which was published in the "Philosophical Transactions for 1802," should be studied as a model of exact scientific research. In the thirty-first volume of the "Annale de Chimie," will be found a very complete list of all those meteoric stones, the period of whose fall can be determined with any degree of accuracy.

A meteoric stone of a remarkable character fell at Ensisheim, near Basle, upon the Rhine.

The account deposited in the church runs thus:—

"A.D. 1492, Wednesday November 7th, there was a loud clap of thunder, and a child saw a stone fall from Heaven: it struck into a field of wheat and did no harm, but made a hole there. The noise it made was heard at Lucerne, Villing, and other places. On the Monday, King Maximilian ordered the stone to be brought to the castle; and after having conversed about it with the noblemen, said the people of Ensisheim should hang it up in their church, and his Excellency strictly forbade anybody to take anything from it. His Excellency, however, took two pieces himself, and sent another to Duke Sigismund of Austria. This stone weighed 255 lbs., and was found to contain iron, nickle, silica, magnesia."

The history and conversion of one of these meteoric masses is too curious to be omitted. In January, 1803, an extract from the autobiographical memoirs of the emperor Jehangire, which had been translated from the original Persian by Colonel Kirkpatrick, was read before the Royal Society. It related to a luminous body, which fell amidst thunder and lightning in 1620; and the following, with a few verbal alterations, are the words of the relation referred to:—"Mahommed Lyeed, the superintendent of the district where the stone had fallen, directed the ground to be dug up, when, the deeper it was dug, the greater was the heat of it found to be. At length a lump of iron made its appearance, the heat of which was so violent, that one might have supposed it to have been taken from a furnace. After some time it became cold, when the superintendent conveyed it to his own habitation, from whence he afterwards despatched it in a sealed bag to court. Here I had," continues the emperor, "this substance weighed in my presence. Its weight was 160 tolahs (five or six pounds). I committed it to a skilful artisan, with orders to make of it a sabre, a knife, and a dagger. The workman soon reported that the substance was not malleable, but shivered into pieces under the hammer. Upon this I ordered it to be mixed with other iron. Conformably to my order, three parts of the *iron of lightning* (or thunderbolt) were mixed with one part of common iron, and from the mixture were made two sabres, one knife, and one dagger.

"A poet composed and presented to me on this occasion the following tetrastich:—

'This earth has attained order and regularity through the emperor *Jehangire*:
In his time fell raw iron from lightning:
That iron was by his word-subduing authority,
Converted into a dagger, a knife, and two sabres.'"

Iron, either in the meteoric state or as projected from volcanoes, may have been found by the ancients, but there is no reason for supposing that any such discovery either suggested or preceded the smelting and use of the metal.

It has been made a question whether the ancient Greeks, towards whom we generally look for authorities as to the early progress of the arts, were acquainted with the uses of iron and steel; at least, whether any explicit mention of these metals occurs in the Homeric poems, the chief sources of our earliest illustrations of their manners and inventions, as identified with the earlier epochs of profane history.

In the description of the games instituted by Achilles on occasion of the death of Patroclus, there is a passage which is thus admirably translated by Cowper, and is generally quoted as express on the point in question:—

> "The hero next an iron clod produced,
> Rough from the forge, and wont to task the might
> Of king Ætion; but when him he slew,
> Pelides' glorious chief with other spoils
> From Thebes conveyed it in his fleet to Troy.
> He stood erect, and to the Greeks he cried:—
> 'Come forth, who also shall this prize dispute.
> How far soe'er remote the winner's fields,
> This lump shall serve his wants five circling years,
> His shepherd shall not, or his plower need
> In quest of iron seek the distant town,
> But hence he shall himself their wants supply.'"
>
> *Iliad*, b. xxiii.

If iron had been in common use among the Greeks in the manufacture of agricultural implements, a lump of that metal of the size assumed by the poet or his translator, might have been no unworthy prize for heroic contention; but, as it is by no means clear that the knowledge of iron for the purpose of military weapons was turned to account, much less can we suppose that the art of subjugating so stubborn a material by the pastoral races was at that time known. Some have supposed that the passage shows that, even if the value of iron was known, the difficulty of working it had not been fully overcome. All translators of the Iliad and Odyssey have introduced the words iron and steel, but this fact constitutes by itself rather a poetical than a philological refutation of the assertion which has been made, that the terms so translated merely mean in the original metals in general; or at most, characterise metals, which cannot be shown to be iron and steel.

Allowing, however, contends the advocate for the affirmative, that the Homeric word *σιδηρος* does, in some places, merely signify metal in the generic sense, still there are many passages where it cannot be so interpreted without violence to the sense. If, therefore, *σιδηρος* does denote any specific metal, it must be *iron*, as contra-distinguished from *χρυσος* and *χαλκος*: silver, lead, tin, nay, copper (*ορειχαλκος*), are known by certain appropriate terms. It seems, therefore, reasonable to appropriate *σιδηρος* for the metal of *iron*, which the poet describes as *αιθων*, splendid or burnished; *στερεος*, firm, hard; *πολνος*, grey coloured; *πολυκμητος*, requiring very much labour to be wrought; *ιοθις*, adapted to the points of missile weapons; besides being used as a simile for hardness of heart, rash bravery, and unpersuadable obstinacy. It has been noticed as remarkable, that Hesiod, an authority at least as ancient as Homer, does not mention iron as forming any part of the armour of Hercules; notwithstanding, in his famous description of the generations of men, he specifies, along with the golden, silver, brazen, and heroic,—the *iron* age, using the epithet ΣΙΔΗΡΕΟΝ. It may be added, that Herodotus bestows much admiration on a vase said to have been of iron, and most curiously inlaid, which was presented by Alyates the king of Lydia, at the shrine of the Delphic oracle: but no safe conclusion, either as to material or workmanship, can be come to from his description, unless the vase itself were forthcoming for our inspection.

Professor Beckmann of Göttingen, whose erudite collections towards a "History of Inventions" have been some time published in this country, in speaking of *steel*, says, "it appears that it was used so early as the time of Homer, and that the Greeks gave to it different names, one of the most common of which was stomoma." The professor, however, does not refer his readers to any particular passages in the Greek poems above mentioned; indeed, he expressly says in another place, that Pliny seems to have used στομωμα to denote copper filings, as others have done. He quotes a passage from the Odyssey, in confirmation of his belief that the art of hardening steel, by immersing it suddenly when red hot in cold water, is very old. Homer says, that when Ulysses bored out the visual orb of the Cyclops, Polypheme, with a stake charred in the fire, the quenching of the red hot wood in the giant's eye resembled what takes place —

> "When the stout smith an hatchet or large adze
> Tempering with skill plunges the hissing blade
> Deep in cold water (whence the strength of steel)
> So hissed the eye around the olive wood." — COWPER.

Sophocles uses the comparison of being hardened like immersed iron.

As the learned foreigner's researches on the subject of steel are curious, and appropriate to the present inquiry, it may be interesting to accompany him somewhat further. He admits that the Hebrews had no particular name for steel, and that there is no evidence to prove that the word *barzel*, translated steel in the authorised version of the Bible, has that specific signification, because the same word is certainly used in many instances to denote iron. The passages, where, from the context, *barzel* has been supposed to mean steel, are mostly those where the expressed use, or implied superiority of the metal referred to, might seem to favour such a conclusion: as Jeremiah, c. xv. v. 12., where "*northern* iron" occurs, seemingly, as some have thought, with reference to Chalybia, the ancient country of steel, and which was situated to the north of Judea: or Ezekiel, c. xxvii. v. 19., where the merchandise of the Tyrians, which in our version is called "bright iron," is by the Latins translated *ferrum fabrefactum;* or, according to Michaelis and others, sabre blades from Usal (Sanaa in Yemen). But to return to the Greeks.—

The word *στομωμα*, which has been already mentioned, does not in the Greek writers appear so much to imply steel, as the *steeling* of instruments, though by what process does not by any means clearly appear. While, therefore, it is admitted that *stomoma* may signify the giving an edge to, or even the hardening the edge of an instrument, it certainly cannot be allowed to mean, what by the term steeling would be meant by a modern artificer, namely, the welding of an edge of steel to a body of iron, or the fastening of it by other means to that or other substances. The same may be said of the expressions of Pliny, — *aciem indurare densare incudes et malleorum rostra ferrum temperare,* — words which, whatever they may mean, are not to be construed as if they had been written by a modern cutler.

From the Chalybes, a people dwelling on the southern shore of the Pontus Euxinus, and who had considerable iron and steel works, has steel derived its Greek name of *χαλυψ*, though some have sought to derive the name of the people from their works. The word *chalybs* was adopted by the Romans from the Greeks, and it has, as the reader will recollect, passed into our own language in the adjective chalybeate, a term used almost familiarly for impregnations of iron or steel.

"I have never found," says Beckmann, "in the works of the ancients any traces of steel prepared by cementation; nor am I acquainted with the antiquity of that process, though the ancients, without knowing it, employed it for brass. Spielman says, that Pliny, in one place, calls it *tostio;* but this word occurs neither in Pliny, nor in any ancient writer. It is, however, possible that *torrere* may somewhere signify cementation, but I have not yet met with an instance of it.

"The preparation, however, by fusion, as practised by the Chalybes, has been twice described by Aristotle. I shall only remark, that the steel of the ancients, in consequence of not being cemented, suffered itself to be hammered, and was not nearly so brittle as the hardest with which we are acquainted at present.

"On the other hand, the singular method of preparing steel employed by the Celtiberians in Spain, deserves to be here described. According to the accounts of Diodorus and Plutarch, the iron was buried in the earth, and left in that situation till the greater part of it was converted into rust. What remained without being oxidated, was afterwards forged and made into weapons, and particularly swords, with which they could cut asunder bones, shields, and helmets.

What may be the peculiar nature of the Celtiberian irons or steels, we are not informed; it is, however, doubtful, if such effects as those referred to in the preceding account, should follow the mere burying of the metal in the ground. Whatever may be thought of the idea, a belief that steel acquires a tenacity by burying it, obtains among the workers in these metals, generally. Certain of the old Sheffield cutlers, who had credit for making first-rate articles in their day, were in the habit of placing bundles of steel in the mud of some watercourse for a few weeks, by which means the metal, although it lost much of its weight by oxidation, was alleged to be much improved in quality. And it is common with scissor-smiths, when they get steel that has a tendency to break on the punching of the hole for the formation of the bow, to place it in a damp cellar for a few weeks, by which treatment having rusted considerably, it is stated to become fit for use. The power of the atmosphere to produce some favourable change in the metal is recognised by country blacksmiths, who, if they want a bit of iron for some purpose where extreme tenacity is required, are anxious to possess themselves of an iron cramp that may have been mouldering for centuries in some stone-work which it holds together, or even some half-consumed hook from an old gate post. It is well known that the iron of old London Bridge was bought at some considerable price, from an idea that it was susceptible of being converted into steel for the finest kinds of cutlery. Plutarch that as steel is only a more perfect kind of iron, therefore the softer and more ignoble part of is first converted into rust, is purely imaginary

Although the evidence which has been quot appear to lead us to the conclusion that iron wa known to the ancients, it is not a little sing nearly all the remains of metal manufacture wh been discovered are in gold, silver, or bron Egyptian bronze figure in the collection of the of Practical Geology was found, when a port was cut off for analysis, to be cast upon a core which was doubtless introduced to give streng casting. The ingeniously constructed spear-hea are found in Roman encampments, the swords, some fine specimens have been found in the river and those curious weapons or tools, distinguishe name of celts, which are found in many parts islands and of the continent, are invariably b nearly the same composition.

Leaving, however, this question for the cons of the antiquarian, we must proceed to the r portant, and no less interesting, examinatio manufacture of iron in England.

CHAP. II.

IRON-WORKS IN ENGLAND.

EARLY IRON WORKS IN BRITAIN. — CÆSAR'S STATEMENT. — SITES OF ANCIENT FORGES. — SUSSEX, GLOUCESTERSHIRE, FURNESS, HALLAMSHIRE. — RELIQUÆ EBORACENSES. — VICISSITUDES OF THE ARTS UNDER THE ROMANS, PICTS, AND SAXONS. — RESPECT PAID TO THE SMITH OF ANCIENT TIMES. — TRADITIONS OF EARLY MANUFACTURES.

At what period the smelting of the iron ore, so abundant in this country, was first undertaken by the ancient Britons, does not exactly appear; it is indeed doubtful whether iron was smelted at all in Britain before the Roman invasion, though, undoubtedly, the knowledge of turning to some account their mineral treasures was possessed by our forefathers at a very remote period. Cæsar states, indeed, that when the Romans invaded Britain, they found the inhabitants in the possession of rings and money of iron: whether these metallic riches were acquired from the Phœnicians in barter for tin, or whether the aborigines then understood the art of working their own mines, may justly admit of dispute. We have no evidence that the Britons knew how to smelt iron when found by the Romans. How shall we receive the testimony of those writers who represent them, even anterior to the Roman invasion, as sufficiently numerous and advanced beyond the savage state, to be able to bring into the field an army of 250,000 warriors, well trained and disciplined, and singularly expert in the management of chariots armed with hooks and scythes, and from which they cast their darts at the enemy? We have no reason for believing the weapons with which these cars were armed to have been of iron; they were probably bronze; still their actual existence would imply a certain advanced state of civilisation and ingenuity.

That a nation losing the knowledge of iron would retrograde to barbarism, is an assertion which, however bold, is not altogether hyperbolical; and the historian of Birmingham, with some confidence, gives it as his opinion, that there is no recorded example of any place, in an improving country like England, where the coarse manufactory of iron, after having been once established, ever went to decay from any cause except the failure of the raw material. It would, however, depose feebly in favour of this sentiment, to admit that the subjects of Caractacus and Boadicea had arrived at that perfection in the working of their native metals, implied by the descriptions of those who speak so glowingly of the scythes and the chariots of the aboriginal Britons.

It is not the design of these remarks, in reducing exaggeration to probability, thereby to defraud our ingenious and valiant ancestors of a particle of their fair fame. Whether the legions of Cæsar found the art of smelting iron practised on their arrival, or whether they taught it to the natives during their sojourn on the island, must probably for ever remain a question. It is certain, however, that from about the period of the Roman invasion, we may date the commencement of our manufactures in metal; ancient beds of cinders, in which have been found Roman coins, confirming the conjecture.

It will be readily admitted, as well by all who are conversant with our early history, as by those who respect traditional probability, that among the earliest uses to which the discovery of malleable iron would be applied, the fabrication of weapons of warfare would not be neglected. In what parts of the island these primitive smelting works were established, we can only judge from presumptive traces: it is reasonable, however, to suppose, that where iron ore at present abounds, especially if scoria occur too, there, in all probability, may we fix the site of the ancient British forge.

Camden, in his "Britannia," has briefly noticed these early seats of our infant iron trade, as well in the county of Sussex as in the forest of Dean, or *Arden* as it was anciently called. Gibson, in his continuation, adds, in reference to the latter place,—"the present forest of Dean contains about 30,000 acres; the soil a deep clay, fit for the growth of oak. The hills are full of iron-stone, which colour the several springs that have their passage through them. Here are several furnaces for the making of iron, which, by the violence of the fire, becomes fluid, and being brought to their forges, is beat out into bars of various shapes. The workmen are very industrious in seeking out the *beds of old cinders*, which, not being fully exhausted, are burnt again in the furnaces and make the best iron. The oak of the forest was so very considerable, that it is said to have been part of the instructions of the Spanish armada to destroy the timber of that place. But what a foreign force could not effect, our own civil dissensions did, for it went miserably to wrack in the civil wars."

Whether the "old cinders" mentioned above indicated the works of our forefathers before the conquest, or whether they are the memorials of a race who had even made some progress in the fine arts, cannot be determined—most likely the latter, as it is certain that iron forges existed in that part of Gloucestershire in the year 1238: for among the patent rolls of Henry III. occurs one dated in the 22nd year of his reign, entitled "*De forgeis levandis in foresta de Dean.*"

Furness, a large insular tract comprised within the county of Lancaster, is said by Camden to have derived its appellation "from the many furnaces therein in old times." Mr. West, in his antiquities of Furness, speaking of the Whitreg mines, now exhausted, but which at a very remote period produced large quantities of ore, calls the district in which they were situate the "Peru of Furness;" the appearance of the ground indicating on every hand the great antiquity of the iron trade in a neighbourhood where it is no longer known to any great extent. The following passage relative to the destruction of the timber in the above-named district is curious:

—"In the seventh year of queen Elizabeth," says M
West, "the woods being greatly reduced, certain bloomaries in High Furness were suppressed at the commo
requests of the tenants of Hawkshead and Colton, tha
the tops and croppings of these woods might be preserve
for the nourishment of their cattle in winter. Th
bloomaries or iron smithies were then leased by Christopher Sandy, gent. and William Sawry, who pai
twenty pounds annually for the wood they consume
At the suppression of the bloomaries, the tenants charge
themselves and their successors with the payment of thi
rent, which is called the *Bloom Smithy*, or *Wood Rent*
and is rated and assessed amongst the customary tenan
at the discretion of four-and-twenty of that body, electe
by a majority of the whole. Since the beginning of th
eighteenth century, the re-introduction of furnaces an
forges for making iron has advanced the value of woo
considerably, and the tenants have found the means o
improving part of their lands into meadows, and preserving their wood for the use of the furnaces."

In the writings of Agricola, published in the year 1556
there is no mention made of the blast furnace as know
to ourselves, although he describes the blast bloomar
and the usual process for obtaining malleable iron.

Pieces of the most fusible iron, he tells us, were introduced into a large crucible in the hearth of the iro
furnace, along with a mixture of flux and charcoal; th
action of the bellows was directed so as to produce fusion
when this was ascertained, four pieces of bar iron, abou
30 lbs. each, were inserted in the fluid, where they remained for five or six hours, till they had nearly absorbe
the melted iron. The masses of malleable iron bein
thus penetrated, enlarged in size and became soft an
pasty. The furnace-man then made a trial of one o
the bars, placing it under a large, or forge, hammer. Th
cake while yet hot was plunged into cold water, and th
fracture examined to ascertain whether it had been a
converted into steel: if this was not the case, a fres
fusion became necessary, and the imperfect steel wa

again inserted for a length of time sufficient for its perfect conversion.

Whether this fusible mixture was in the first instance grey cast-iron, or iron containing less carbon, it will hardly be contended that it did not become so when fused in contact with flux, in a crucible containing pounded charcoal. Besides, it is not altogether improbable that some particular qualities of ore, finely reduced and added in sparing quantities compared with the mass of the fuel (at that time wood charcoal), were found to yield, even in the low ancient bloomary, what is now so generally known to us under the name of grey cast-iron.

A little further examination into the history of the *first production and use of cast-iron*, cannot fail to prove interesting.

Although no mention is made in the works of the Saxon Agricola, of a blast or other furnace, or any process pointed out for obtaining cast-iron, yet this substance seems to have been known to him, and is described as being used for the purpose of converting malleable iron into steel. It is exceedingly probable that, by the means of the blast bloomary, it was first called, by accident, into existence, centuries before the art was discovered of converting it into malleable iron. It might even in the first instance, by means of large crucibles or clay pots, have been formed and cast into shape. M. Verlit says, that cast-iron was known in Holland in the thirteenth century, and that stoves were cast from it at Elass, in the year 1400. If such was the case, such iron must either have been produced in clay pots, or obtained by means of a larger furnace than the largest of those used as blast bloomaries, for the production of malleable iron, as the quality of the cast-iron, from which stoves were likely to be cast, would require to be carbonated, and to which in this age we give the name of foundery-iron. Cannon were used by the English at the battle of Cressy, in 1346; and if stoves were made of cast-iron so early as the year 1400, the periods approach each other so nearly, that a question may be fairly raised whether the cannon so employed were made of cast-iron; a circumstance not at all probable, unless they were foreign-castings: for the first iron guns cast in England were in 1547, by a person in London of the name of Owen, who in 1535 had succeeded, for the first time, in making guns from brass or bronze. Cannon and gunpowder are mentioned in a record of the chamber of Paris accounts in 1338, eight years before the battle of Cressy, but no mention is made as to the nature of the metal of which the former were composed. At or about that period, it is fair to presume that artillery had become an object of considerable importance in the estimation of the war-going states of Europe. In the year 1368, there was an officer in the French army called the master of the king's cannon. The Venetians used cannon at the siege of Claudia Jessa in 1366, and when at war with the Genoese in 1377; they were also used by the Turks before Constantinople in 1394, and at its last and fatal siege by Mohammed in 1453. "Fourteen batteries," says Gibbon, "thundered at once upon the more accessible places of that great city." There is no distinct allusion made to the metal of which any of these battering cannon were formed. From the circumstance of the Turks not being able to fire their early guns more than twice a day, it is probable that these were constructed of staves of wrought iron, bound together by strong hoops of the same metal, but which, with heavy charges, frequently burst in the firing, so as to require repairs almost after every discharge. In 1468, James II. of Scotland lost his life before Roxborough Castle by the bursting of a cannon similarly constructed. Not so made, however, were the other cannon used at the great siege of Constantinople, which Gibbon represents as having been cast,—a circumstance almost incredible, if the number and magnitude of the pieces are taken into the account, but if correct, conveying to us, in the present day, a very high opinion of the genius and resources of the conqueror of the Greeks. At a later period, Sully, in his Memoirs, speaks of a noble park of artillery he had at the arsenal of Paris; but as no mention is made of iron, it is more reasonable to conclude that they were, as well as those used at Constantinople, made of a mixture of copper and tin, commonly called bronze.

Hutton, in his History of Birmingham, remarks, that upon the borders of the parish stands Aston furnace, appropriated for melting iron-stone, and reducing it to pigs. "This has the appearance of great antiquity. From the melted ore in this subterranean region of infernal aspect, is produced a calx or cinder, of which there is an enormous mountain." From an attentive survey, the observer would suppose so prodigious a heap could not accumulate in one hundred generations; however it shows no perceptible addition in the age of man.

Mr. Hunter, the Sheffield historian, has some pleasing and pertinent passages on this subject. Having described, under the ante-Norman period of his work, the ancient class of tenantry called *Villani*, he says:—"But when we consider the mineral riches of the district, we can hardly hesitate to believe that to these another numerous class is to be added. Bede, in the eighth century, mentions iron among the mineral productions of this island; and the remarkable fact, that in the midst of a mass of scoria the refuse of some ancient bloomary, near Bradford, was found a deposit of Roman coins, seems to leave it indisputable that the iron mines of Yorkshire were explored by its Roman inhabitants. No where did the ore present itself more obviously, by tinting with its beautiful ochre the beds of the streamlets in its vicinity; no where did it lie nearer to the surface; no where could there be greater facilities for subjecting the ore to the processes necessary to extract from it its metal, than in the forest through which the Don poured its waters. Many beds of scoria of the kind just mentioned are found in various parts of the parish of Sheffield, where there is now no tradition nor any record of works of iron ever having existed. They are found even in the park which for many centuries past has been peculiarly appropriated to the pleasure of the lord. Over most of them the soil has so accumulated as to form a very thick crust, in which trees of ancient growth are at this moment flourishing. The probabilities are therefore strong, that before the Norman invasion, and that even while the Romans had possession of the island, the iron mines of Sheffield afforded employment to a considerable number of persons, some to draw the ore from its bed, others to extract from it the metal, and a third class employed in fabricating weapons, implements of husbandry, or domestic utensils.

"The silence of Doomsday Book affords no presumption against the validity of this conclusion. Miners or artificers of any class, rarely came under the notice of the compilers of that survey. In the lead districts of Derbyshire, we have no notice of the persons employed in mining or in smelting the ore, although mention is made of the quantity of lead which the owners of some particular manors were to render to the king. Doomsday must, therefore, be considered as neutral in this question: and in almost the very next in chronological order of the records from which we obtain our knowledge of the early state of this neighbourhood about the year 1160, we have notice of pretty extensive iron works established at Kimberworth by the monks of Kirkstead.

By what methods precisely our rude forefathers conducted their smelting processes so as to obtain malleable iron, we are not informed; though, as may presently be shown, the difficulties which they would have to overcome might be neither so many nor so formidable as some persons have imagined. But whether the Britons were indebted for their first knowledge of the art of subjecting iron, or merely for their improvement in that art, to their invaders the Romans, it appears to be admitted, that the latter established founderies for making iron, and erected manufactories of spears, battle-axes, and other implements, in almost every section of the kingdom conveniently adapted for such a trade. Nor need it be dissembled, that probably under those able instructors our ancestors acquired a proficiency in the working of iron, and thus laid a foundation for that celebrity which their posterity in after ages has so justly obtained.

In the fragment of an ingenious Latin poem, by Dr. Dering, dean of Ripon, entitled "*Reliquæ Eboracenses,*" Sheffield is feigned, "with due regard to historical probability," to have been the place from which the Brigantes were supplied with the arms with which they waged war with the invading Romans; the industrious artisans being represented as hanging up before them armour taken from the foe, as patterns by which to fabricate their own: —

> "Mille ardet Sephilæa focis. Fornace liquescit
> Montibus effossi vicinis massa metalli;
> Et longe resonat glomeratis ictibus incus:
> Nec lunæ aut cotis cessat labor. Insuper arma
> Ante oculos fabri ponunt Romana; notantque
> Mutandum siquid; seu sint exempla sequenda."

An intelligent iron-master, to whom the present work owes many of its details, believes that when the Romans began to establish their *bloomaries*, Hallamshire, for so has the district around Sheffield since been named, was one of the first of their factories.

After the departure of the Romans the arts began to ebb: at peace for so long a series of years, the inhabitants had almost forgotten what war meant; and, accustomed to the manufacturing of ploughshares and pruning-hooks, they might only remember, as things once heard of, the names of arms. Aroused from this state of torpidity by their northern neighbours, they suffered all the effects of a predatory war before they ventured on resistance; unarmed and dispirited, they appear to have sunk almost without a struggle. The frequency of insult at length aroused their native energy; but military prowess, much less military accoutrements, cannot be created in a day: hence those armies which formerly had made even Romans tremble, were no longer terrible to an inferior enemy. Their weapons were useless from want of exercise, and all their efforts only served to extend the ravages of their invaders, by making manifest the feebleness of the resistance opposed to them. Aided, however, by the Saxons, they drove the barbarous hordes of Picts again into the north, but submitted to those as masters whom they had invited as allies. Thus the ill-fated country, from a lamentable want of unanimity, had been successively enslaved by the Romans, the Picts, and the Saxons—it changed its tyrant, but not its servitude.

Mingling by slow degrees, the Saxons and the Britons in time formed but one people. The frequent quarrels of the princes of the heptarchy rendered the manufacture of arms again a work of necessity. The *Deiri*, supporting their prince by a liberal supply of weapons, and of soldiers hardy enough to use them, seated their Edwin on the throne of Northumbria, and supported him against the attacks of the infamous Penda; and he, in return, encouraged the arts of peace. For him the south Deirans are presumed to have tried a new fabric with their iron, for he had a number of iron dishes forged, which were fastened with chains beside the various springs and fountains which lay on the route generally travelled from one town to another, so that passengers might refresh themselves on their journey. According to local accounts, vestiges of these benevolent arrangements have not long since existed in that part of *Deira* which is comprehended within the wapentake of Strafforth and Tickhill.

The Norman conquest again laid waste the country in many districts, especially in the north, where William met with the most determined resistance, and from whence it is probable the arms of the natives were principally derived. But, wherever may have been seated the principal forges of that period, it is certain that the army of Harold was well supplied with swords and spears, and defensive armour; and, moreover, that a considerable degree of expertness had been acquired in the fabrication of articles from the anvil. One of our historians observes, that immediately preceding the conquest "the art of working in iron and steel had arisen to such a state of improvement, that even the horses of some of the chief knights and barons were covered with steel and iron armour. Artificers, who wrought in iron, were so highly regarded in those warlike times, that every military officer had his smith, who constantly attended his person to keep his arms and armour in order. The chief smith was an officer of considerable dignity in the court of the Anglo-Saxon and Welsh kings, where he enjoyed many privileges, and his weregeld was much higher than that of any other artificer. In the Welsh court the king's smith sat next to the domestic chaplain, and was entitled to a draught of every kind of liquor that was brought into the hall:" a privilege which many artificers of his class in our own day will not be disposed to make light of!

Although so considerable a degree of perfection appears to have been attained at a very early period in the working of iron, and even of steel, the art of casting articles in sand from the metal in its crude state seems to have been either unknown or not at all practised till a comparatively recent period; unless, indeed, we may be allowed to imagine, with the old poet, that the primitive artificer, seeing the liquid metal run from his furnace,

"In two square creases of unequal sizes,
To turn two iron streamlings he devises:
Cold, takes them thence; then off the dross he rakes;
And this a hammer, that an anvil makes."

Large heaps of scoria are found in many parts of England and known as the *Danes' Cinders*, which would appear to refer to smelting operations carried on by the Northmen. In 1620, oaks of a large size were growing in these cinders; they must therefore be referred to an early date. Dudley informs us, that in 1615 there were 300 blast-furnaces at work, producing 180,000 tons of iron, requiring 144,000 tons of charcoal, for which 17,310,000 cubic feet of timber were necessary, and 500 forges and iron mills for refining were said to be at work. The following extract from *Dud Dudley's*

Metallum Martis, printed 1665, is a curious record of the introduction of coal for smelting iron.

"That Great Brittian with her men of warr, fleets, and shiping, have had in all ages, and in these latter ages, as great success at seas as any people whatsoever in the universe, cannot modestly be denied; in 88, overthrowing that invincible armada so long a preparing; and since, other navies also; and whose armadoes, navies, armees, and men, have been a terrour to other nations; nay, her own grand magazines are the very granary from whence all His Sacred Majestie's kingdomes, dominions, and territories, both in the East and West Indies, on this side and beyond the line, they have their whole and thorow supply of shiping, men, armes, food, and rayment, and more than can be from any kingdom of the Christian world. Now if wood and timber should decay still, and fail, the greatest strength of Great Brittian, her ships, mariners, merchants, fishings, and His Majestye's predecessors, Queen Elizabeth and her great council, the then parliament, to make lawes for the preservation of wood and timber, especially near any navigable river; 1 Eliz. 15.; 27 Eliz. 19.; 28 Eliz. 3. 5.; 23 Eliz. 5. All which laws, and others, for the preservation of wood and timber, are still in force, but not duly executed; also King James, his Sacred Majestie's grand-father, and Prince Henry, for the preservation of wood and timber in this island, did, in the ninth year of his reign, grant his letters pattents of priviledge unto Simon Sturtevant, Esq. for thirty-one years, for the making of iron with pit-cole and sea-cole, for the preservation of wood and timber of Great Brittian, so greatly then consumed by ironworks. This invention was, by King James's command, to be at large put in print, which book did contain near a quire of paper in quarto, called Simon Sturtevant, his Metallica, anno 1612, May 22, printed by George Eld, cum privilegio. After Simon Sturtevant could not perform his making of iron with pit-cole or sea-cole according unto his engagement, King James and Prince Henry caused him to render up his pattent, and a new pattent was granted unto John Ravenson, Esq., who also was enjoyned to write a book of his inventions, called Ravenson's Metallica. Printed for Thomas Thorp, cum privilegio; May 15, anno 1613.

"After John Ravenson, Esq. had often failed with his inventions and great undertakings, — Gambleton, Esq., a servant of Queen Ann's, undertook (by pattent) to perform the invention of making of iron with pit-cole and sea-cole; but he being as confident of his invention as others, did erect his works at Lambeth, which the author viewed; and Gambleton failing, the learned and ingenious Doctor Jorden, of Bath, the author's acquaintance, and sundry others, obtained pattents for the making of iron, and melting of mines with pit-cole and sea-cole, for the preservation of wood and timber; all which inventions and endeavours to effect and perfect the said works have been by many heretofore well known to have worthily attempted the said invention, though with fruitless success. Having seen many of their failings, I held it my duty to endeavour, if it were possible, to effect and perfect so laudable and beneficial, and also so much desired inventions, as the making of iron into cast works and bars; and also the melting, extracting, refining, and reducing all sorts of mines, minerals, and metals, with pit-cole, sea-cole, peat, and turf, for the preservation of wood and timber so much exhausted by iron works of late. Having former knowledge and delight in iron works of my father's when I was but a youth, afterwards at 20 years old was I fetched from Oxford, then of Bayliol Colledge, anno 1619, to look and manage three iron works of my father's, one furnace, and two forges, in the chase of Pensuet, in Worcester-shire; but wood and charcole growing then scant, and pit-coles in great quantities abounding near the furnace, did induce me to alter my furnace, and to attempt, by my new invention, the making of iron with pit-cole, assuring myself, in my invention, the loss to me could not be greater than others, nor so great, although my success should prove fruitless; but I found such success at first tryal as animated me, for at my tryal or blast I made iron to profit with pit-cole, and found facere est addere inventioni. After I had made a second blast and tryal, the fesibility of making iron with pit-cole and sea-cole, I found by my new invention the quality to be good and profitable, but the quantity did not exceed above three tuns per week. After I had brought my invention unto some perfection, and profitable, doubted not in the future to have advanced my invention to make quantity also. Immediately after my second tryal, I wrote unto my father what I had done, and withall desired him to obtain a pattent for it, from King James of blessed memory; the answer to which letter I shall insert, only to show the forwardness of King James in this his much animating the inventor, as he did both Simon Sturtevant, John Ravenson, Doctor Jordanie, and others.

"'Son Dudley,

"'The King's Majesty being at New-market, I sent Parkes thither on Saturday to some friends of mine, to move the King's Majesty for my pattent, which be coming on Sunday morning; in the afternoon, His Majesty sent a warrant to Master Atturney to dispatch my pattent, for the which I am infinitely bound unto His Majesty, that pleased him of his great grace and favour to dispatch it so soon. I have been this night with Master Atturney, who will make hast for me. God bless you; and commend me to all my friends.

"'Your loving father,
"'EDWARD DUDLEY.

"'March 10, 1619.'"

As is usual with all new introductions, Dud Dudley's suffered much from the prejudices of the times, as the following additional extract from the "Metallum Martis" proves:—

"Afterwards the author was outed of his works and inventions before mentioned by the iron-masters and others wrongfully, over long to relate; yet being unlling his inventions (having undergone much charge d pains therein) should fall to the ground, and be ried in him, made him to set forward his invention ain at a furnace called Himley Furnace, in the unty of Stafford, where he made much iron with pit-le; but wanting a forge to make it into bars, was nstrained for want of stock to sell the pig-iron unto e charcoal iron-masters, who did him much prejudice, t only in detaining his stock, but also disparaging e iron; Himley Furnace being rented out unto arcole iron-masters. The author erected a new large rnace on purpose, 27 feet square, all of stone, for his w invention, at a place called Hasco Bridge, in the rish of Sedgley, and county of Stafford; the bellows which furnace were larger than ordinary bellows are, which work he made 7 tuns of iron per week, the eatest quantity of pit-cole iron that ever yet was made Great Brittian; near which furnace the author dis-vered many new cole-mines 10 yards thick, and iron-ne under it, according to other cole-works; which e-works, being brought unto perfection, the author s by force thrown out of them, and the bellows of new furnace and invention by riotous persons cut in ces, to his no small prejudice, and loss of his inven-n of making of iron with pit-cole, sea-cole, &c. So at, being with lawsuites and riots wearied and dis-led to prosecute his art and invention at present, even till the first pattent was extinct, notwithstanding, the thor, his sad sufferings, imprisonments wrongfully r several thousand pound in the Counter, in London, t did obtaine a new pattent, dated the 2nd of May, nno 14 Caroli Primi of ever blessed memory, not ly for the making of iron into cast-works and bars, ut also for the melting, extracting, refining, and re-ucing of all mines, minerals, and metals with pit-cole, a-cole, peat, and turf, for the preservation of wood nd timber of this island; into which pattent the uthor, for the better support and management of his invention, so much opposed formerly at the Court, at the Parliament, and at the law, took in David Ramsey, Esquire, resident at the Court; Sir George Horsey, at the Parliament; Roger Foulke, Esquire, a counsellor of the Temple, and an ingenious man; and also an iron-master, my neighbour, and one who did well know my former sufferings, and what I had done in the invention of making of iron with pit-cole, &c. All which said pattentees articled, the 11th of June following, the grant not only to pay the author all the charges of passing the pattent laid down by him, but also to lay in for a common and joynt stock, each man of the four, one hundred pounds, and so from time to time what more stock any three of the pattentees should think fit to be laid in for the making of iron into cast-works and bars, and likewise for the melting, extracting, refining, and reducing of all mines, minerals, and metals, with pit-cole, sea-cole, peat, and turf, which articles are yet extant."

The history of smelting iron with pit-coal forms so important a section in the history of our metal manufacture, that it is thought advisable to add some further particulars to this chapter.

Pit-coal had been long known. It was wrought at Newcastle prior to the year 1272. Annually vast quantities of it were exported to Holland and the Low Countries, for the use of the smithy, and other manufactures requiring an intense and continued heat. Yet in England prejudices ran so strong against its application to the manufacturing of cast or malleable iron, that the projectors of this useful undertaking met with every obstacle which the narrow, unenlightened minds of the established manufacturers could devise.

James granted several patents for the exclusive right of manufacturing iron with pit-coal. None of the projectors, however, were successful till 1619, when Dudley succeeded in making coke pig-iron, though only at the sparing rate of three tons per week. By this time many of the iron-works were at a stand for want of wood; the consequence was an advance on the price of iron; this, therefore, rendered it a lucrative business to those manufacturers whose supply of wood was still undiminished, and of course made them hostile to any innovation whereby the price of iron was likely to meet with a reduction.

This period of prejudice, so unfavourable to innovation in the iron business, was followed by one more general and more calamitous for the nation. Amidst the distraction occasioned by civil war, neither innovation nor improvement could be expected. Patents, however, were granted to some during the Commonwealth, for the exclusive manufacture of iron in the new way, in one of which Cromwell was a partner. These partly shared the same fate as did their predecessors, and none succeeded in establishing a manufactory either of extent or of certainty. In 1663, we find Dudley applying for his last patent, and setting forth, that at one time he was capable of producing seven tons of coke pig-iron weekly, with an improved furnace twenty-seven feet square, and bellows which one man could work for an hour without being much tired. It was not till impelled by necessity by the rapid decline of the annual growth of timber, that pit-coal became an object of universal estimation. When the improvements on machinery had attained a pitch of certainty, and experience had taught the mechanic the manifold advantages to be derived from the steam-engine, men of industry and enterprise began to think of extending the manufactures of the country in iron with pit-coal. Small furnaces supplied with air from leathern bellows, worked by oxen, horses, or human labour, became exploded, and an increase of size took place, together with an increase of the column of blast necessary to excite combustion. But as it seldom happened, that to the advantage of having pit-coal, ores, and limestone concentrated in one spot, water also was added, it became necessary to form a substitute. For this purpose, the steam-engine, that superhuman invention, was applied. Rude and unpolished no doubt were its early designs and execution—rapid, however, have been its improvements; and at the present time, by many it is believed to have arrived at the highest possible pitch of human perfection. With the improvements in machinery the advancement in the practice of manufacturing coke pig-iron kept pace; and it is now a certain truth, that with pit-coal in our time we produce a quality of pig-iron superior for every purpose of the arts (bar-iron making excepted) to that at any time made with charcoal of wood, and in the following increased proportion:—

Average annual produce of a charcoal furnace 180 years ago - - - -	600 tons
Some furnaces in England on an average now produce 40 tons per week - - -	2,080
Value of the former when manufactured, *6l.* per ton	3,600*l.*
Value of the latter on an average of the qualities, *6l.* 10*s.* - - - - -	13,520*l.*

By comparing the value of pig and bar-iron at present with what it sold for 230 years ago, an accurate notion may be formed of the increased price of labour and materials attached to iron-work.

	Per Ton. £	Per Ton. *s.*
About the year 1620 charcoal pig-iron sold for -	6	0
In the year 1792 carbonated pig-iron sold for -	8	10
In the year 1798 „ „ -	10	0
Coke pig-iron when invented sold for - -	4	0
In the year 1792 melting pig-iron sold for -	5	10
In the year 1798 „ „ -	7	10
Malleable iron made with charcoal sold for -	15	0
The same in 1792 to be drawn into wire for -	23	0
„ in 1798 - - - 27*l.* or	28	0
The first bar iron made (1620) with pit-coal sold for - - - - -	12	0
The same iron in 1792 sold for - - -	18	0
„ in 1798 for - - -	22	0

The modern prices will be found in a future page.

For many of these particulars we are indebted to the valuable papers published in the "Philosophical Magazine" by Mr. David Mushet, and afterwards reprinted under the title of "Papers on Iron and Steel." To the same authority are we indebted for the additional notice.

"ON THE INVENTION AND ESTABLISHMENT OF THE BLAST-FURNACE IN ENGLAND.

"The opinion which I had formed when the text was first printed, in favour of the blast-furnace for the production of cast or pig-iron, being an English invention, has since that period been corroborated by various circumstances. The fact of Owen casting iron guns in 1547, would indicate a knowledge of the re-melting of iron, and is a considerable confirmation of the previous existence of the blast-furnace, and of its productions in the shape of castings of various sorts, a great variety of which would most likely be first fabricated before commencing upon pieces of ordnance. It is fair also to presume, that pig-iron would be well known, and applied for the purpose of making bar-iron long before it became a staple article in the manipulations of the foundery. From documents which have since come into my possession, I am not now inclined to fix so early a period as is assigned in the text to the introduction of the blast-furnace into the forest of Dean; and although the furnace, the age of which is therein roughly inferred, from the accumulation of cinders, may be considered as amongst the first, if not the very first, erected in that neighbourhood, yet it ought to be considered of more recent introduction than was at first inferred. The calculation of age which proceeded upon the assumption of a certain weight of cinder being obtained in the production of a given weight of iron, and which with a rich ore may be correct; yet on further consideration of the subject, and taking into account the calcareous nature of the iron ores of Dean forest, requiring a considerable portion of argillaceous schist to neutralise the lime, it is more than probable, that the furnace would necessarily, from this circumstance and from the inferior produce of the ores, produce fully as much cinder as pig-iron; and that in place of only being one half the weight, it probably would be of equal weight with the iron. Taking the calculation in this way, we should not reach an older period than the commencement of the seventeenth century for the introduction of the blast-furnace into Dean forest. As a proof that pig or cast-iron was made in England antecedent to this period, we have not only the fact of guns being cast from it in 1547, and mortars and other artillery during the reign of queen Elizabeth, but I happen to have, through the kindness of my friend Mr. Hill, of the Plymouth Iron-works, in my possession, a perfect casting, on which are inscribed the arms of England with the initials E. R., and bearing date 1555, being the last year of the reign of Edward VI. There is no clue to its history or how it came into possession of Mr. Hill, but it has evidently been used as a back-plate to a very large grate or fire-place, as there has been on its lower edge a considerable action by fire. There are the remains of a charcoal furnace on the west side of the river Taffe, opposite to the Plymouth Iron-works, where probably this casting was made, and at once run from the blast-furnace, though it is difficult to account for its having upon it the arms of England, as before mentioned. At one time I was inclined, from this circumstance, to consider it as a relic that had been cast at one of the king's furnaces in Dean forest, and which afterwards had been carried into Glamorganshire; but I am now satisfied, from its early date, that this could not have been the case, and that it is far more probable it was cast at the before-mentioned furnace, which was situated about two miles below Merthyr Tydvil, where either the kings of England had in that age possessions, or the proprietor enjoyed a license under one of the great monopolies generally held by the nobility, and common to that age, on the condition of affixing the royal arms to the productions of his foundery. The quality of the iron from which this casting is made, is what in the present time would be called strong forge iron, mottled towards the edge, which gives hardness and great strength.

"*The king's furnaces in the forest of Dean* claim particular attention as illustrating a period when the kings of England were iron-masters, or at least lessors of what at that early period were considered extensive iron-works, particularly in the forest of Dean.

"From a survey made and dated the 23rd of September 1635, it appears, that the kings of England stood possessed of three blast-furnaces and two iron forges within the forest. From having had an opportunity of examining, about twenty-five years ago, the hearths of one of these furnaces, at that time discovered under a considerable thickness of soil, I was led to conclude, from the smallness of the dimensions, that these furnaces belonged to the first or early class alluded to in the text. Their names are as follow: — Parkend blast-furnace, Cannop blast-furnace, Sowdley blast-furnace, Parkend forge, and Sowdley forge.

"In the survey just alluded to, these furnaces are sometimes called forges, from the circumstance of this being the term given to iron-works previously to the invention of the blast-furnace, where, at the bloomaries, malleable iron only was made, and where the operation of the hammer was hourly required, to give solidity and form to the manufactured iron. All these furnaces seem to have been planted upon the sites of extensive bloomary operations, which for many years afterwards furnished ample supplies of cinder to mix with the native ore in the blast-furnace, for the production of pig-iron. At what precise period the king's furnaces were erected does not appear; but from an old record we are informed, that James I., in 1622, demised all his iron-works in Dean forest to two persons, of the names of Harris and Chaloner, for a period of twenty-one years, in which it was agreed, that the miners of the forest should furnish the king's furnaces, as they were called, with the necessary supplies of iron ore for the furnaces at the same price, and on the same terms, which they had been formerly obliged to supply the iron-works of the king. Previous to the above demise, and in the return of Sir William Coke and others to a commission issued out of the Exchequer in 1617, to inquire into the affairs of Dean forest, it is expressly stated, that his majesty

James I. had. since the erection of the iron-works, *i. e.* the new furnaces for making pig-iron, received a greater revenue than formerly; leaving it to be inferred, that these furnaces had been first erected in that reign, and had been found more profitable than the bloomaries. That the blast-furnaces had been already erected in the ninth of James, is made evident from a patent granted to the earl of Pembroke of all the king's iron-works in the forest, including the iron ore, and corwood to make charcoal, for the annual sum of 2433*l.* 6*s.* 8*d.*, a very large rent in those days, when the value of money at that period is taken into consideration, and could only have arisen from the high expectations at that time entertained from making iron in the new way. It would appear, from the same document, that the lessee, determined to make the most of his bargain, wished to have confined the whole of the mining operations in the forest to the supply of the furnaces which he rented under the king, and to have prevented the miners from carrying the iron ore and cinders elsewhere, which probably he found it difficult to do, as other furnaces were either erected, or being erected, in the purlieus of the forest, the proprietors of which naturally became competitors in the mine market for a supply of ore for their furnaces. An information was, therefore, lodged by his lordship in the Exchequer against several of the miners on this account, and a decree obtained, that in consideration of the high rent paid by his majesty's farmer, Lord Pembroke, the miners should be allowed to continue their labours, but on the condition of carrying the iron ore and cinders to his majesty's forge, *i. e.* blast-furnaces. The mention of cinders in this decree is at once a proof of the existence of the blast-furnace in 1612, where they could only be smelted to any advantage. It does not appear for what reason the demise between the crown and the earl of Pembroke terminated, or what led to the new demise in favour of Harris and Chaloner, whether from the highness of the rent, or whether from the refractory disposition of the miners, relying upon what they considered their ancient rights, which to a considerable extent seems to have left them an open market for the produce of their mines; and this may be gathered from their book of old customs. In these no allusion is made to the king's iron-works, but only to that share of the mines with them to which they considered the king entitled, and probably from which source the royal furnaces derived the principal part of their supply of iron ore."

The following accounts of the present condition of the iron-works of the United Kingdom, are taken from the very valuable communication of Mr. S. H. Blackwell of Dudley, to the Illustrated Catalogue of the Great Exhibition.

"The gross annual production of iron in Great Britain, is now upwards of 2,250,000 tons. Of this quantity South Wales furnishes 700,000 tons; South Staffordshire (including Worcestershire) 600,000 tons; and Scotland 600,000 tons. The remainder is divided amongst the various smaller districts. One of the principal causes of the advantages possessed by Great Britain in the manufacture of iron, arises from the number and variety of the measures of argillaceous and black-band ironstones, which alternate with the beds of coal in almost all its coal-fields; and in consequence of which, the same localities, and, in many instances, the same mineral workings, frequently furnish both the ore and the fuel required to smelt it. So extensive are the ironstone beds of the coal measures, that they furnish in themselves the greater part of the iron produced in Great Britain; but the iron-making resources of the kingdom are by no means confined to them. The carboniferous, or mountain limestones of Lancashire, Cumberland, Durham, the forest of Dean, Derbyshire, Somersetshire, and South Wales, all furnish important beds and veins of hæmatite; those of Silverstone, Whitehaven, and the forest of Dean are the most extensively worked, and seem to be almost exhaustless. The brown hæmatites and white carbonates of Alston Moor and Weardale also exist in such large masses that they must ultimately become of great importance. In the older rocks of Devon or Cornwall are found many important veins of black hæmatite, and in the granite of Dartmoor numerous veins of magnetic oxide and specular iron ore. The new red sandstone furnishes, in its lowest measures, beds of hæmatitic conglomerate. In the lias and oolites are important beds of argillaceous ironstones, now becoming extensively worked; and the iron ores of the greensand of Sussex, once the seat of a considerable manufacture of iron, will, in all probability, again become available, by means of the facilities of railway communication. The produce of the manufacture of iron in Great Britain in 1750, was only about 30,000 tons; in 1800, it had increased to 180,000 tons; in 1825, to 600,000 tons; in the following year the duties upon the introduction of foreign iron were either removed or rendered nominal, since which the production of iron has nearly quadrupled itself, being now about 2,250,000 tons."

The following is Mr. Blackwell's estimate of the number of blast-furnaces in and out of blast in 1850:—

	In.	Out.
South Wales, eastern outcrop - -	12	11
„ north-eastern outcrop - -	42	8
„ northern outcrop - -	60	10
„ central anticlinal district -	10	10
„ western district - -	12	22
„ southern outcrop - -	7	4
North Wales - - - -	3	2
Shropshire - - - - -	23	10
North Staffordshire - - - -	13	8
South Staffordshire - - - -	105	43
Yorkshire, north district - - -	10	6
„ south district - - -	5	8
Derbyshire - - - - -	19	10
Northumberland, Cumberland, and Durham	19	19
Lancashire and West Cumberland - -	3	
Forest of Dean - - - -	5	

CHAP. III.

SMELTING.

SOW OR PIG METAL. — HYPOTHESIS OF SMELTING. — INDICATIONS OF ANCIENT BLOOMARIES. — METHOD OF MAKING IRON AT CUCKFIELD, IN SUSSEX, IN THE SEVENTEENTH CENTURY. — EVELYN'S EXECRATION OF IRON MILLS. — EFFECTS OF SUBSTITUTING PIT-COAL FOR WOOD FUEL. — MODERN SEATS OF THE IRON MANUFACTURE IN ENGLAND. — NATIVE ORES. — COKING. — THE BLAST-FURNACE. — BLOWING MACHINERY.

IRON, either in the state into which it is first reduced by fire, previously to its conversion to the condition of malleability, or as it is used for the casting of large articles in moulded sand, is called *sow metal* or *pig metal*, epithets originating with the furnace-men, and referring to the blocks as they may have been run in the main or the collateral gutters, the former being called *sows*, and the latter *pigs*, respectively: the material is in each sort the same, being in fact the metal in its simplest available state, immediately on its running from the ore.

The earliest operations of smelting in this, as in other countries, would, we may suppose, be extremely simple. According to the hypothesis before mentioned, the putting a quantity of ore upon a heap of wood, and setting the pile on fire, in conformity to the manner in which ores are presumed to have been melted during the burning of forests, was, it may be conjectured, the first rude process by which metals were extracted. But as the force of the fire is greatly diminished when the flame is suffered to expand itself, and as the air acts more violently in exciting to a fierce heat when it rushes upon the fire with greater velocity, — a phenomenon too obvious to be neglected even by barbarians, — it is likely that the heap of wood, or charcoal, would soon be surrounded with a wall of stone, in which sufficient openings would be left for the entrance of the air, and thus a kind of furnace would be constructed. The Peruvians, we are told, had discovered the art of smelting silver, either by the simple application of fire, or, where the ore was more stubborn and impregnated with foreign substances, by placing it in small ovens, or furnaces, on high grounds, so artificially constructed, that the draught of air performed the functions of a pair of bellows,—a machine with which they were unacquainted. The use of the bellows was certainly known in England at a very early period, though the precise era of their introduction is not ascertained. A rude contrivance, answering the purpose well enough, is constructed by the Hottentots themselves, who have long understood the methods of smelting both iron and copper, — a knowledge of which they might have acquired from the Dutch settlers. Their furnaces are described as of a conical form, and built of clay, which becomes almost as hard as stone. A round opening is left at the top for receiving the ore, and underneath a space for the fire: the pile is open before and behind, not only for admitting the fuel, but the operation of the rude bellows, consisting of a skin bag distended and compressed by the hands.

The heaps of cinders found in various parts of this kingdom, especially in Yorkshire, indicate unequivocally the situations of ancient bloomaries. These are met with as well in the valleys as on the hills: the latter, however, have been supposed to belong to the earlier works, and to a period anterior to the knowledge of bellows. This has been partly inferred from the remarkable fact, that the cinders found on elevated spots almost invariably contain a large quantity of metal; the ore, on account of the inefficiency of the mere air draught, not having been thoroughly reduced. On the other hand, the slag found in low situations, where it is presumed the furnaces were worked after the introduction of bellows, is in most cases so completely exhausted, as not to be worth the trouble of re-smelting, even with modern machinery.

In the sixteenth century the process, according to all accounts, was not many degrees advanced, with the exception of the bellows and a better constructed furnace, beyond the primitive practice. What it was in 1674, may be seen from the following extract from an account of the manner of making iron at Cuckfield, in Sussex; it was written by that observant naturalist and philosopher, John Ray, F.R.S.: —

"The iron *mine*[*] (ore) lies sometimes deeper, sometimes shallower in the earth, from four feet to forty, and upwards.

"There are several sorts of mine; some hard, some gentle, some rich, some coarser. The iron-masters always mix different sorts of mine together, otherwise they will not melt to advantage.

"When the mine is brought in, they take small cole (charcoal), and lay a row of small cole, and upon it a row of mine, and so alternately, *stratum super stratum*, one above another, and setting the coles on fire, therewith burn the mine. The use of this burning is to mollify it, that so it may be broke in small pieces; otherwise, if it should be put into the furnace as it comes out of the earth, it would not melt, but come away whole.

"Care also must be taken that it be not too much burned, for then it will loop, *i. e.* melt and run together in a mass. After it is burnt, they beat it into small pieces with an iron sledge, and then put it into the furnace (which is before charged with coles), casting it upon the top of the coles, where it melts and falls into the hearth in the space of about 12 hours, more or less, and then it is run into a sow.

"The hearth or bottom of the furnace is made of a sand stone, and the sides round, to the height of a yard, or thereabout; the rest of the furnace is lined up to the top with brick.

"When they begin upon a new furnace, they put fire for a day or two, before they begin to blow: they then blow gently, and increase, by degrees, till they come to the height, in ten weeks or more.

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[*] *Mine* is still commonly the term used to signify iron ore; in the same manner as we find it employed by Ray in the above instance.

"Every six days they call a *founday*, in which space they make eight tons of iron; if you divide the whole sum of iron made by the founday, for at first they make less in a founday, at last more.

"The hearth, by the force of the fire continually blown, grows wider and wider: so that if at first it contains so much as will make a sow of 600 or 700 pounds weight, at last it will contain so much as will make a sow of 2000 pounds. The lesser pieces of 1000 pounds, or under, they call pigs.

"Of twenty-four loads of coles, they expect eight ton of sows; to every load of coles, which consists of eleven quarters, they put a load of mine, which contains eighteen bushels.

"A hearth ordinarily, if made of good stone, will last forty foundays; that is, forty weeks, during which time the fire is never let go out. They never blow twice upon one hearth, though they go upon it not above five or six foundays.

"The cinder, like scum, swims upon the melted metal in the hearth, and is let out once or twice before a sow is cast."

Sussex, previously to the use of pit-coal in smelting, was one of the principal sources from which English iron was drawn; at present, the smelting in that county has totally declined, as old Evelyn predicted it would, in consequence of the wasting of the forests. The consumption of charcoal for the smelting of iron has been one chief cause of the great destruction of our ancient woods. Evelyn has beautifully observed, that "Nature has thought fit to produce this wasting ore more plentifully in woodlands than any other ground, and to enrich our forests to their own destruction:" to which he elsewhere adds his "*Diræ*, a deep execration of iron mills, and iron-masters also, *quos ego* —" "How would he have rejoiced," exclaims Mr. Hunter, "to have witnessed the day when the coke of pit-coal became substituted for the charcoal in this consuming process!" The sylvan beauty of Sussex, indeed, appears to have been chartered to special spoliation; for, by the act of 1st of queen Elizabeth, chap. 15., it is enacted, that no oak, beech, or ash timber, of the breadth of one foot square at the stub, shall be cut down to be converted to charcoal for making iron, in any parts of the kingdoms of England and Wales, except in the county of Sussex, in the weald of Kent, and certain other parishes in the latter county.

It was the introduction of charred pit-coal, or coke, that not only arrested the destruction of our forests, but laid anew the foundation of our present extensive manufactories of native iron. Up to the last-mentioned period, small furnaces were generally made use of, and these were, as already observed, heated with charcoal in the same manner as is still practised in many places on the Continent. So long as England abounded with wood, the process was carried on to considerable advantage; and we find that the manufacture of iron was in a flourishing condition in the reign of James I.: but, from that time, the increase of inhabitants and of cultivation, and the subsequent decrease of wood, caused this business to decline so greatly as to be nearly lost, until the substitution of coal restored to our country this important trade.

A few words on the iron-making localities appear necessary.

The iron ores obtained from the extensive district of South Wales are principally argillaceous, and these are found in connection with the beds of coal in this division, which are on the eastern side entirely bituminous. In the eastern outcrop of the South Wales coal-field there are, however, found some beds of black-band or carbonaceous ironstone. In the central portion, on which are situated the Cwm Avon and other extensive works, occur some of the most important beds of black-band ironstone occurring in South Wales.

Passing to the western district, we find the coal converted gradually and at length entirely into anthracite, and all the beds of iron ore bear the appearance of having been subjected to an exceedingly high temperature, by which, without doubt, the bituminous coal has been changed into anthracite. The annual production of iron on the southern outcrop of the South Welsh coal-field is about 25,000 tons.

In North Wales the production of iron is limited to a small district, the only works being those of Rhuabon and Brymbo.

Shropshire produces about 90,000 tons of iron annually; the ironstones being in nearly all respects similar to those used in South Staffordshire. The annual production of iron in South Staffordshire and Worcestershire is nearly 600,000 tons. This is considered one of the most important iron-making districts in the kingdom. The production of pig-iron in Scotland is equal to it; but the quantity of wrought iron made in Staffordshire is far superior to that of Scotland.

The North Staffordshire coal-field contains a larger number of beds of ironstone than any other; most of the ores are, however, sent to South Staffordshire to be smelted, the district therefore producing only 55,000 tons of iron annually from its thirteen furnaces in blast.

Yorkshire produces annually 25,000 tons of iron of very superior quality in its northern division, and about 20,000 tons in its southern division.

Derbyshire produces about 60,000 tons a year, Northumberland and the northern adjoining counties showing an annual production of 90,000 tons. The works in this district are very rapidly increasing in importance, the cost of fuel being so low as to permit ores to be brought from many different localities. The black-band ironstones of Scotland, and of Haydon Bridge, the white carbonates and the brown hæmatites of Alston and Weardale, and the argillaceous ironstones of the lias formations of Whitby and Middlesborough, are all used to supply these works.

The brown hæmatites of this district are more important; they contain from 20 to 40 per cent. of iron. Sometimes these ores exist as "riders" to the lead-veins, and sometimes they exist in mass, attaining occasionally to the thickness of from twenty to fifty yards.

Lancashire and West Cumberland are remarkable for the manufacture of charcoal iron, at Ulverstone; otherwise the works are not of any considerable importance.

The ores of Whitehaven, Ulverstone, and Furness are raised extensively for shipment to the iron-works of Yorkshire, Staffordshire, and Wales. They are the finest iron ores of the kingdom, and yield from 60 to 65 per cent. of iron.

The ores of Dean forest are carboniferous, or mountain limestone ores, and from these there are produced by smelting, in the forest, about 30,000 tons: a large quantity of ore is, however, sent to South Wales.

The micaceous iron ores of Dartmoor, and the magnetic oxides of iron, are only just beginning to attract attention.

Hæmatite conglomerates are found extending over a large portion of Gloucestershire, Somersetshire, and Devon. Portions of them are now worked and sent to South Wales. The greensand formations of Sussex, containing large quantities of iron, were formerly worked; but the wood becoming exhausted, the works were abandoned. The black-band formations of Scotland, to which attention was first called by Mr. Mushet, have become of great importance. Of the coals raised in Lancashire more than one half is employed in the iron-works of the district.

The following table shows the chemical constitution of many of the more important iron ores.

	Per-oxide of Iron.	Pro-toxide of Iron.	Alumina and Silica.	Carbonic Acid.	Oxide of Man-ganese.	Lime.	Zinc.	Water.
Brown iron ore -	82·90	-	3·60	-	1·0	-	-	12·50
Specular iron - -	94·00	-	2	-	-	1·0	-	3
Magnetic iron ore	69·00	31·0						
Franklinite - -	66·00	-	1	-	16	-	17	1
Silicate of iron -	-	52·54	29	-	1·58	12	-	1·25
Carbonate of iron	-	57·50						
" "	-	54·57	-	36·0	3·30	1·25	-	25
Pitchy iron ore -	31·0	-	-	-	42·0	3·2[*]		

[*] *As phosphate of lime.*

When Dr. Colquhoun published his paper on the Scotch iron-works, only two analyses of any British specimen of iron ore have been published: one of an ore from Colebrook Dale, in Shropshire, examined by that eminent French chemist Descostils; and one of an ore from the vicinity of Bradford, in Yorkshire, examined by Mr. Richard Phillips. The following information on this interesting subject cannot fail to be acceptable even to the non-chemical reader, as exhibiting that variety of aspects under which this valuable base of so large a proportion of our mineral riches is presented to the manufacturer or the philosopher:—"Had this ore, the most important of all our minerals," says Dr. Colquhoun, "been as rare as it is common, or had it been brought from a great distance abroad, instead of being found in a happy profusion at home, it is hardly to be doubted that long ere now the pages of our scientific journals would have exhibited an accurate exposition of its nature and history. But since the fact is so, it is at least an agreeable task to furnish some materials towards supplying the deficiency; and therefore the following mineralogical analyses are subjoined, from an examination of nine specimens which were taken from regular strata in the great coal-field that lies around Glasgow.

	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)	(*g*)	(*h*)	(*i*)
Water - - -	- -	0·99							
Carbonic acid	32·53	33·63	31·86	30·76	26·35	33·10	32·24	35·17	34·27
Protoxide of iron - - -	35·22	45·84	42·15	38·80	36·47	47·33	43·73	53·03	42·35
Protoxide of manganese -	0·00	0·20	0·00	0·07	0·17	0·13	0·00	0·00	
Lime - - -	8·62	1·90	4·93	5·30	1·97	2·00	2·10	3·33	3·78
Magnesia - -	5·19	5·90	4·80	6·70	2·70	2·20	2·77	1·77	4·95
Silica - - -	9·56	7·83	9·73	10·87	19·90	6·63	9·70	1·40	12·70
Alumina - -	5·34	2·53	3·77	6·20	8·03	4·30	5·13	0·63	
Peroxide of iron - - -	1·16	0·00	0·80	0·33	0·40	0·33	0·47	0·23	
Calcareous or bituminous matter - -	2·13	1·86	2·33	1·87	2·10	1·70	1·50	3·03	
Sulphur - -	0·62	0·00	0·00	0·16	0·00	0·22	0·02	0·00	
Moisture and loss - - -	- -	- -	- -	- -	1·91	2·26	2·34	1·41	1·95
	100·37	100·68	100·37	101·06	100·00	100·0	100·00	100·00	100·00

"(*a*) From Crossbasket, about seven miles south-east from Glasgow. Colour light-greyish, or greenish-black. Fracture, from fine-grained even to coarse-grained, uneven, very easily frangible, soft, easily scratched by the knife. Specific gravity taken in distilled water at the temperature of 60°, 3·1793.

"This is the highest and also the least valuable of the Crossbasket strata of ironstone, which are at present raised for the use of the blast-furnace. The thickness of the stratum is from three to three and a half inches.

"(*b*) From Crossbasket. Colour light greyish-black. Fracture fine-grained, earthy, slightly uneven. Rather tough. Not particularly soft. Specific gravity 3·3801.

"This ore is found at a distance of four feet under the preceding one. It constitutes a stratum of about nine inches in thickness, and is esteemed the purest and most valuable of the Crossbasket ores.

"(*c*) From Crossbasket. Colour light greyish-black. Fracture fine-grained, earthy, slightly uneven. Rather tough, but more easily frangible, and softer than the last-mentioned ore. Specific gravity 3·2699. The average thickness of the stratum is from six to eight inches.

"(*d*) From Crossbasket. Colour brownish-black. Fracture earthy, fine-grained, uneven. Easily frangible and soft. Specific gravity 3·1175.

"This stratum of ironstone is situated next under that from which the preceding specimen was taken, and forms the lowest which is at present wrought at Crossbasket. It varies in thickness from ten to fourteen inches. Both it and the preceding ore are reckoned of good average quality. This ore furnishes a curious instance of the capricious and seemingly unaccountable alterations that are liable to take place in every chemical manufacture, whose fundamental principles are little understood, and in none, perhaps, does this happen more frequently than in the smelting of iron. Although it forms the thickest of all the Crossbasket strata, and therefore holds out powerful inducements, in an economical point of view, to the iron smelter, it was at one period regarded at the Clyde iron-works as an ironstone totally unfit for the manufacture of good iron; and having once received an unfavourable character, it was allowed to remain unworked for a long course of years. It is only of late that its employment has been again resumed; but, so far from being held in low estimation, it is now considered to be little inferior in quality to any of the Crossbasket ores, and is used very extensively in the blast-furnace.

"Immediately above this stratum there is situated a bed of schist, containing a regular stratification of very large nodules of ironstone. Being extracted by the miner simultaneously with the subjacent ore, they are used to a considerable extent in the blast-furnace, and are esteemed an ironstone of uncommonly fine quality. The black bituminous substance which occurs occasionally in nodular ironstone, exists very generally distributed throughout this stratification of balls.

"(*e*) A specimen found in the neighbourhood of Clyde iron-works, which are situated about four miles south-east from Glasgow. Its mineralogical details are the following:—Colour pale, between brocoli-brown and clove-brown. Fracture rather fine-grained, uneven. Not particularly hard, easily scratched by the knife. Specific gravity 3·1482. The thickness of the stratum is about two inches and a half. It is considered at the works to be an ore of a very inferior quality, and is seldom smelted.

"Immediately above this ore there is situated a bed of schist, which contains an immense number of petrifactions of different kinds of bivalve shells: they consist of *a very pure ironstone*, resembling in appearance the subjacent land.

"(*f*) Their forms are remarkably perfect, and they contain no visible remains of the original shell.

"(*f*) An ore lying under the last-mentioned stratum, and in close contact with it. Colour between yellowish-grey and hair-brown. Fracture fine-grained, earthy, even. Rather hard; scratched with some difficulty by the knife. Specific gravity 3·2109. The stratum to which it belongs is situated above the splint coal, with the intervention of only four inches of schist, and both minerals are therefore worked out together with great advantage to the smelter. It is the most valuable ore in all the fields around Glasgow, except that called the *black ironstone*, which is at present smelted at the Clyde iron-works. The thickness of the stratum is between one and a half and two inches.

"(*g*) This specimen was procured from Easterhouse, near the line of the Monkland Canal, and about six miles east from Glasgow. Colour clove-brown. Fracture fine-grained, rather uneven. Somewhat tough and hard, but easily scratched by the knife. Specific gravity 3·3109.

"This ore exists in precisely the same relative situation, with regard to all the other accompanying minerals, as the two ores from the Clyde iron-works, which have just been described; and wherever it makes its appearance, it seems to have been produced by the coalescence of these two strata. This compound stratum has always a uniform texture and composition throughout. Its average thickness is two and a half to three inches. It is used pretty extensively in the blast-furnace, and is esteemed an ore of good average quality.

"(*h*) From the neighbourhood of Airdrie, about ten miles east from Glasgow. Colour clove-brown, the intensity of the shade varying considerably in streaks which are parallel to the direction of the stratum. When reduced to powder the colour is brown. Fracture fine-grained, earthy, rather uneven. Tough, and difficultly pounded; communicating a feeling of elasticity under the pestle. Rather hard; scratched by the knife. Adheres slightly to the tongue, a property which did not appear to be possessed in a sensible degree by any of the ores already described. Specific gravity 3·0553. Numerous bivalve shells, of a pale wood-brown colour, occur scattered through the mass of this ore, and form a strong contrast with its darker shade. This is one of the valuable iron ores of Scotland, where it is fami known under the name of *black ironstone* or *Mu black band*. The latter appellation has been given the circumstance that it was first smelted by Mr. Mu to whom we have already referred as the metall most distinguished for his practical skill.

"It lies about fourteen fathoms below the fifth gow coal-bed, or splint coal, and constitutes a layer fourteen inches in thickness. It is remarkable t has hitherto been found nowhere except in the n bourhood of Airdrie; although several attempts been made in other localities to reach it by boring. the Clyde iron-works, it is justly regarded as the est and most valuable ore which they at present po

"(*i*) From a stratum situated in the vicini Crossbasket. Colour bluish-grey. Fracture, in great, even; in the small, very fine-grained, ea rather hard.

"Such was the composition and mineralogical d of various specimens of ironstone, which were obt from component strata of the independent coal form around Glasgow. It is well known that this ore pre itself not only in uninterrupted strata or *bands*, a miners term them, but also in the form of indepe nodules or *balls*, imbedded in a stratum of some fo mineral."

Iron ore is not unfrequently found in a re stratum, occupying the whole space between the above and below it. When the strata, usually a laminated or ochrey clay, are not more than tw five or thirty feet in depth, they are procured by ing a pit first, about eight feet in diameter, whi enlarged as the depth increases, until the ironstone reached; the pit is undermined, until at the bo it becomes twenty feet diameter, and of a conical fi when all the stones contained in the pit are taken another is sunk so near the former that it will m at the bottom. The earth taken from the secon is thrown into the first, and in this manner the work proceeds until the depth becomes greater: it is then the most economical method to work a mine under ground, in the same manner as for coals. It frequently happens that an iron furnace is situated where coals are mined at a considerable depth, while the ore is procured nearer the surface; by this arrangement, the same expense of machinery serves for drawing off the water from both.

Iron masters generally consider, that with the same proportion of fuel, the best iron will be produced from the argillaceous ores; that is, combining strength and a moderate degree of fusibility. Calcareous ores afford iron which melts easily, though it is deficient in strength; when manufactured into bar-iron, it becomes what the workmen term *red short*, that is, brittle when hot. The metal produced from ironstones, containing nearly equal mixtures of sand, clay, and lime, have an intermediate degree of fusibility and softness, but is generally very strong. The worst crude iron is obtained from argillaceous ore: it is unfit for any purpose in this state, and when rendered malleable becomes *cold short*, or brittle when cold.

The first operation to which the iron ore is subjected, is wasting; that is, exposing the stones to a moderate heat, which volatilises any extraneous mixture of the ores.

Roasting in the open air in heaps requires some short description. This mode of calcining ore is undoubtedly the most available, and that generally practised. It affords by good management excellent results. To form a heap or heaps, the ground must be levelled, and in many cases covered with beaten clay. The area of such a level depends entirely on the amount of ore to be roasted, and the time in which it is proposed to be done. It may be laid down as a rule, that the longer the fire remains in a pile, or the slower the roasting is carried on, the better will be the result. If the time is limited, rows of three feet high, from seven to eight feet wide at the base, and of convenient length, may be put up and fired. These rows may be finished in ten or twelve days; but though they answer well enough for hydrates, sulphurets, carburets, and all those ores which calcine easily, they do not answer for magnetic ore or carbonates. For those ores which are roasted with difficulty, round or square piles of various dimensions are used; some of these piles have a capacity of from 100 to 2000 tons. The amount of ore in fire should depend mainly on the stock on hand, and on the quality of the ore. Magnetic ore may be roasted in the course of six or eight weeks; argillaceous ores of the blue or grey kind, require at least three months; and the sparry carbonates can scarcely be roasted in one heat, frequently require different fires, and after all are but seldom sufficiently calcined. In Styria, Carinthia, and other places, where heavy sparry iron ore abounds, and where good iron must be delivered, the iron masters are compelled to have a stock of ore sufficient to supply the furnace for a number of years; and the complicated manipulations by which the sparry carbonates are oxidised, often require a period of from three to five years. The operation is there mainly conducted on the principle of oxidising by the influence of the atmosphere; for that purpose the ores are broken into small fragments of the size of walnuts, then spread upon level plains in a thin stratum of about two inches thick and exposed to the action of the sun and atmosphere; in dry weather the ores are sprinkled with water once or twice a day. Ores oxidised in this way are, of course far superior to those oxidised by means of artificial heat which operation is performed as follows:—Billets o wood are placed, like the bars of a gridiron, upon a previously prepared level spot; sometimes they are laid parallel, and sometimes in a crosswise manner, so as to form a uniform flat bed. The crevices between the wood may be filled with chips of wood, charcoal, turf, or even stone-coal, coke, or anthracite, so as to prevent the ore from falling between the other pieces of fuel, or, what is stil worse, upon the ground. The ore, before it is put upon the fuel, should be broken in [illegible] f uniform size, o from three to four inches in diameter; the larger pieces to be used inside of the pile, the smaller ones for covering. When a foundation of fuel of about eight inches high is prepared, ore may be piled upon it to the height of from eighteen inches to two feet; upon this ore is spread a layer of small charcoal or of turf, coke, or small anthracite coal, in a uniform thickness of two inches, or one inch of fuel to one foot of ore; then alternate beds of fuel and ore, until a sufficient height is reached. The pile thus prepared, whether of an oblong, square, or round form, should be covered with small ore, and then should be set on fire either in the centre, for which purpose one or more holes or flues are left, or around the base. After the fires are properly kindled, the piles may be covered with riddlings of ore or small coal. The combustion should proceed slowly, being somewhat suffocated, so that the whole mass may be uniformly penetrated with heat. Where the fire is too intense, it must be covered with small ore or coal-dust; and where it is too imperfectly developed, holes should be pierced with an iron bar, that smoke and air may have vent. In all cases of calcining in heaps, the arrangement and manipulation are almost the same, with hardly any other variations than those arising from the difference of ore and fuel.

Next in importance to the quality of the iron ore is the management of the coke, which has superseded the use of charcoal in the process of smelting. On its first introduction, the coals were merely piled on a heap, ignited, and, when sufficiently burnt, the heat was smothered by covering the pile with dust and sand. Since the matter has been better understood by practice, and a knowledge of chemistry, more perfect and economical methods have been adopted: these consist generally in the use of close furnaces or ovens, mostly contiguous to the iron-works, and under the same management. Parkes has described the hemispherical ovens for the burning of coke, which exist in the neighbourhood of Sheffield; they are about ten feet wide at the base, and two feet at the aperture: the wall of brick eighteen inches in thickness.

"When these ovens are once heated, the work goes on night and day without interruption, and without any further expense of fuel. It is conducted thus:—small refuse coal is thrown in at the circular opening at the top, sufficient to fill the oven up to the springing of the arch; it is then levelled with an iron rake, and the doorway on the side built up with loose bricks. The heat acquired by the oven in the former operation is always sufficient of itself to light up the new charge, the combustion of which is accelerated by the atmospheric air that rushes in through the joints of the loose bricks in the doorway. In two or three hours the combustion gets to such a height, that they find it necessary to check the influx of the air; the doorway is therefore now plastered up with a mixture of wet soil and sand, except the top row of bricks, which is left unplastered all night. Next morning, when the charge has been in twenty-four hours, this is completely closed also; but the chimney remains open till the flame is gone, which is generally quite off in twelve hours more; a few loose stones are then laid over the aperture, and closely covered up with a thick bed of sand or earth. All connection with the atmosphere is now cut off, and in this situation the whole remains for twelve hours to complete the operation. The doorway is then opened, and the cokes are raked into iron wheelbarrows to be carted away. The whole operation takes up forty-eight hours; and as soon as the cokes are removed, the ovens are again filled with coal for another burning. About two tons of coals are put in for each charge, and the cokes produced are ponderous, extremely hard, of a light grey colour, and shine with metallic lustre.

"When coke is required to be more of the nature of charcoal, the process is conducted in a different manner. The small coal is thrown into a large receptacle, similar to a baker's oven, previously brought to a red heat. Here the door is constantly open, and the heat of the oven is sufficient to dissipate all the bitumen of the coals, the disengagement of which is promoted by frequently stirring with a long iron rake. The coke from these ovens, though made with the same kind of coal, is very different from that produced by the former operation; this being intensely black, very porous, and as light as pumice stone." Both these descriptions of coke enter into the process of smelting; the former is capable, not only of acquiring an intense heat, and lasting a considerable time, but likewise of sustaining a great weight of ore in the furnace without presently falling to ashes; the latter sort are more inflammable, but considerably less durable.

Evelyn, in the sixteenth century, complained most pathetically, that nature had thought fit to place the most accessible iron ore immediately beneath our most extensive and flourishing forests. After describing some sylvan giants, he exclaims, "What a pity such goodly creatures should be devoted to Vulcan!" How often do we accuse Providence when our own short-sightedness alone prevents us from perceiving the admirable beauty and economy which runs through all the arrangements of nature! The "wasting ore," which our amiable philosopher seemed to regard merely as the bane of those noble wood-growths which he so enthusiastically admired, has of late years been shown to exist most largely and opportunely with the coal formations in general. The following reflections of Dr. Colquhoun, on this important fact, are of a character widely different from the lamentations of the author of Sylva. "To such perfection has the process of manufacturing iron by the coke of pit-coal now been carried, that this mineral has not only almost entirely superseded the employment of wood, but it has been the means of advancing the manufacture itself in this country, to an extent which is unparalleled in the history of any other age or nation. It has now been ascertained by long experience, that there is no other fuel which is so well fitted at once to supply the heat of the furnace, and at the same time to endure the powerful blast which is incessantly forced upon it. It may now be said to be essential to our iron manufacture, which would, indeed, be almost annihilated were the supply of it withdrawn. How great a source of admiration and gratitude must it always be to regard the immense profusion in which this valuable mineral discloses itself, and the intimate connection and neighbourhood which subsists between it and the ore of iron! How important are its inexhaustible treasures to the country, which must otherwise have been compelled either to relinquish the manufacture of iron, or lay under wood immense tracts of what are now fertile corn-fields, in order to supply, at an enormous expense, a much more imperfect fuel for the furnace! Nor is it possible to omit contemplating one of the momentous consequences of such an order of things, those subterranean labourers who, in many districts of the island, pursue with incessant toil their invaluable occupation. A shaft is sunk, wide excavations are opened up, and tier above tier, at various depths below the surface of the earth; and sometimes below the bed of a river, or of the ocean itself, a succession of extensive sheets are seen to penetrate the bowels of the earth: so that in a tract of country which for ages may have been regarded as an unproductive waste, numerous villages, with their busy throng of inhabitants, find an existence, which would never have been theirs but for the fruitful source of wealth that is yielded by the coal mine. And thus it happens, in many parts of this industrious and enterprising country, that a dense population are making the bosom of the earth to resound with the pickaxe below, while the surface is opened by the plough above, or, it may be, is furrowed by the rapid keels which bear abroad the commerce of Great Britain."

The exterior fabric of a blast-furnace, or stack, as it is called generally, as is well known, resembles a truncated pyramid, constructed within of fire-proof materials, and without of brick or stone, according to circumstances.

The shape of the internal orifice has been compared to a wine decanter placed upon a funnel, the greatest diameter of which is equal to the bottom of the decanter. The dimensions may be as follows:—The total height of the furnace fifty feet, the width of the top four feet diameter, the middle thirteen feet, the bottom two feet square, which is placed upon the end of a trough, six feet long, two deep, and two wide, called the hearth. The blast is introduced immediately above the hearth by a pipe of about two inches diameter on each side: of course before the metal on its extraction from the ore can descend into the hearth, it must pass the narrowest and hottest part of the furnace.

Figs. 1. and 2. represent a vertical section and the ground plan of a common coke blast-furnace, reduced from the working plan of a practical builder.

Fig. 1.

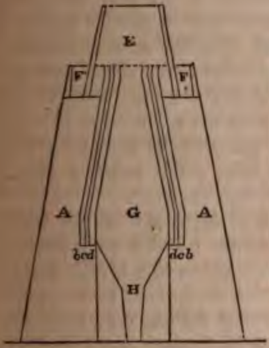
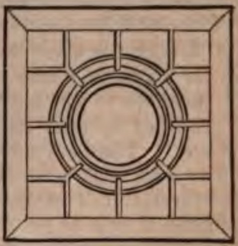


Fig. 2.



A A (*fig.* 1.), the outer stack or building composed of Ashler stone or common brick.

b b, an inner casing of masonry, about fourteen inches thick, which, when the furnace requires to be renewed inside, admits of being taken down and rebuilt, without injury to the outer fabric.

c c, a space of six inches filled with river sand, compactly rammed in: this medium, being but an indifferent conductor of heat, tends to preserve the casing last described.

d d, a coating of the best fire bricks, fourteen inches in thickness.

E, a semicircular wall, eight or nine feet high, for the purpose of preventing the wind from blowing the flame upon the men or the machinery employed in serving the furnace.

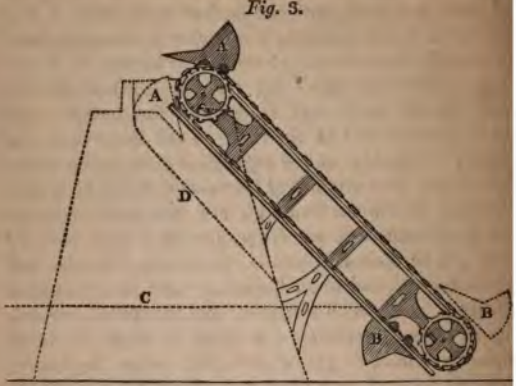
F F, a lower wall, surrounding the one last mentioned, on the summit of those furnaces which are of old construction, as supplied by men from baskets, &c.

G, the inside of the furnace, for the reception of the materials during the process of fusion. The metal, as disengaged from the ore, descends by the pipe H into the hearth or receptacle in the centre of *fig.* 2., which is composed of similar materials with the superstructure.

The double lines converging from the sides, and carried through the outer circle in *fig.* 2., are simply open gutters left in the stonework by some builders, as vents for the escape of any small quantities of air which may be generated by what they term "the swelling of the furnace." These are not always inserted.

For some time after the construction of the larger blast-furnaces had obtained, the method of supplying the materials was by the construction of a sort of bridge, or slightly ascending road from the ground to the mouth of the furnace. Along this road the ore, fuel, lime, &c. were carried by the workmen in baskets, and thrown in at the burning crater. This mode was superseded by the construction of a metal railway, inclined at an angle of about 45° from the ground to the orifice of the stack. Along this an iron corve or waggon, with a slide bottom, to which was fixed a projecting bar, was made to move by means of a chain connected with a water-bucket in an adjoining pit, and the bottom of which was furnished by a clack or valve. This vessel and the corve were properly counterpoised, and so arranged that when the bucket was at the bottom of the pit, the corve was over the aperture of the furnace, and when the former was at the pit mouth, the latter was on the ground to receive its charge. The operation was this; when the corve was filled with materials, and the bucket with water, a bolt was drawn, which allowing the bucket to descend, drew the corve up the rails, till it came over the mouth of the furnace, when the projecting rod striking first against a plate on the back wall forced out the bottom, and allowed the contents of the corve to fall down into the furnace; the bucket at the same time coming into contact with the pit bottom had its valve opened, by which contrivance the water ran out, and the preponderance being thus restored to the corve, the latter descended of course. The inclined plane is still retained, but instead of the old corve and water bucket, an iron box, mounted on wheels, and called a *tippler*, and somewhat resembling in shape a common coal skip, is made to travel completely round, or rather *over* and *under* the plane, which consists of two tracks of parallel rails. This tippler, A A, *fig.* 3., on turning at the top of its course, discharges its contents, by that inversion of its right position, from whence its trivial name is derived: it then travels down the lower plane, and round the bottom wheel, as indicated by the positions B B, the dotted or right hand figure showing its place, when receiving its charge of materials, supplied from corves on the floor level C. The motion of these feeders is derived from a track chain attached to the wheels of each; for there are two of them, one always at the top, when the other is at the bottom, and passing over spiked wheels, the lowermost communicating with a revolving shaft from the steam engine. This latter wheel, both for safety and convenience, is placed at the extremity of the rails below the floor. It may be observed, too, that in order to allow the feeders to traverse the upper portion of the inferior rail, a space corresponding with the size of the vehicle is cut in the front of the furnace, in the direction of D. It is hardly necessary to say that the cut represents a profile or side view of the rail-course, divested much as possible of whatever would have obscured t intelligible simplicity of its principles.

Fig. 3.



When a furnace is first set to work, fire is put in the bottom: it is then gradually filled with coke, a care is taken not to heat it too rapidly, the time requi for this purpose being ten or twelve days, and dur which period only a small quantity of air is permit to enter at the bottom. As soon as the fire has completely through the cokes to the top of the furna they are drawn out at the bottom, and the furnace k full as the cokes sink with a small quantity of ironsto limestone, and cokes. When the ore appears at bottom, the opening is stopped up, and the blast set work: this is termed blowing-off. The fusion of the then takes place; in a few hours the hearth fills w metal and cinders, during which time it is frequen stirred and worked about by the furnace men with i bars suitable for the purpose. As the metal accumulates, its superior weight it displaces the cinder or *slag*, wh is continually running over, and is conveyed away by workmen. Generally in from twelve to twenty-f hours, according to the quality of the ore and the size of the furnace, the hearth becomes full of metal; it is then, by the removal of a luting of clay, let out at the end of the hearth, and permitted to run into beds of sand previously moulded into pigs, or channelled so as to communicate with the moulds of any other heavy articles that may be about to be cast.

About every half hour the furnace requires what is termed a half charge, viz. twenty-four stones of cokes, nearly the same of iron ore, and six or seven stones of limestone. These proportions will vary according to the state of the furnace, which is affected by the atmosphere, the quality of the materials used, and also the quantity of metal wanted. It would certainly be a matter of astonishment to our forefathers, could they witness the magnitude of our present furnaces; and the ponderous machinery employed to excite the blast. Instead of two or three men, as formerly, working a clumsy pair of bellows, it is now common to employ steam engines of twenty or thirty horse power, being near a hundred fold greater, and the furnaces are of forty or fifty times the capacity of the old ones.

The apparatus for blowing varies considerably in the mechanical construction: the most common arrangement is to have a cylinder at the end of the engine beam, closed at both ends, with a piston moving throughout its length. Thus, when it is expelling the air at one end, it is receiving it at the other, and so on alternately. It is evident, however, that this would produce an irregular blast, but partially answering the purpose; to remedy the defect at some furnaces, they have another cylinder connected with the air pipes open at top, and in which works a weighted, or what is called a fly-piston, the use whereof is this:—when the first piston is reversing its motion, the fly-piston descends, but when the former is in the middle of its stroke the latter descends; and by this means the blast is regulated.

Another method consists in the use of what are called water-bellows; these machines depend on the principle,

that a stream of water running through a pipe, if
means it is mixed with air at its entrance, wil
that air along with it again as soon as it comes ou
pipes ; the air then being collected by a proper app
it may be used with success for exciting the mo
lent degree of heat. Dr. Lewis has made a grea
experiments on this blower ; one objection to
however, has always been the degree of humidit
which the blast has been loaded. The most ap
method, therefore, is to compress the air into
called a dry regulator ; this is merely a large me
about three yards square and ten or fifteen lon
fectly air-tight. Instead of a square box, large
globes are frequently employed. The elastic
the air, which increases with the compressing
causes it to issue from either of these vessel
perfectly regular blast. This mode is consider
best, from its regularity, and because the air is fr
moisture. At length, the experiment of heati
air, previously to its being blown into blast-fu
was tried with success. It was long doubted b
tical men, whether the expense of making the
would not counterbalance the subsequent gai
reverse of this was found to be the result of
severing trial made at the Clyde iron-works. A
works the air, before it is thrown into the bla
naces, is heated to 220° Fahr. in cast-iron vessels,
on furnaces similar to those of steam-engine
The value of the application of the hot blast
best understood by remembering that cold air
into a furnace must, in becoming heated to the
necessary for increasing the energy of combustio
sorb some portion of the heat already generated.
take as an example two furnaces, one supplie
hot and the other with cold air, the result will b
the temperature of the former will, in the same
become very much higher than the temperature
latter. Experiment and calculation have show
by sending in air which has been raised previo
the temperature of 572° Fahr. instead of 60° F

furnace may have its temperature raised about one eighth; so that if the temperature of a cold-blast furnace be on the average 2650° Fahr., we may by the hot blast increase this to 3000°. Consequently, fusion is effected in a hot-air furnace much more readily than where cold air is employed.

The apparatus by which the air is heated to a proper temperature is usually a stove around which is arranged a series of tubes, through which the air is made to circulate before it arrives at the nozzle through which it enters the furnace.

On this point Mr. J. Arthur Phillips remarks:—

"Experience has shown, that if a furnace going well with the ordinary cold blast be afterwards supplied with heated air, the amount of fuel added may be considerably reduced without affecting the proper working of the apparatus. The substitution of hot air instead of cold, nevertheless, materially affects the nature of the reactions which take place in the different parts of the apparatus. The amount of combustibles being diminished, and the quantity of air supplied from the tuyeres being in proportion to the weight of the fuel used, it necessarily follows that the amount of gas passing through the furnace is much less in proportion to the mineral employed than in a furnace working with a cold blast. If, then, the temperature of the hearth, notwithstanding the diminished quantity of fuel, be assumed to be the same as if cold air were employed, it follows that all the upper and middle parts of the apparatus must be cooler in furnaces where the hot blast is used, than in those in which cold air only is injected. The fuel, also, from being more readily consumed when brought in contact with the highly-heated air, requires less time to unite with the oxygen of the blast; and the extent of the zone of maximum temperature will be therefore proportionally diminished. These causes are the means of producing a great difference in the nature of the chemical actions produced in various parts of the furnace; and from this circumstance the products obtained by the hot blast are found to differ considerably from those yielded by the old process. When the hot blast is employed, the fuel used is generally uncoked coal."

The experiments at Clyde iron-works show that the air is heated in the separate furnace with one eleventh part of the fuel that is required to heat it in the smelting furnace, when allowed to come in contact with the coke. One reason why this should be the case is obvious: in the smelting furnace the air is heated with coke, in the separate furnace with coals. It appears, then, when the volume of air injected by the tuyere is either too great, or driven too violently forward, instead of promoting combustion in the ratio of its impetus, it is carried through the materials unconsumed, the cokes at the same time being blown away before they can efficiently co-act with the fluxes; in consequence of which the ore falls either not at all, or but partially liquefied, into the hearth below. To avoid this evil, and at the same time to bring the blast to bear upon as large a surface as possible, it has been introduced on opposite sides of the furnace, and by this means it has been most largely and economically applied. Another phenomenon is the well-established and important fact, that the produce of blast-furnaces in almost all cases, and in some instances the quality of the metal, is very materially affected by the season of the year. In some furnaces, indeed, the decreased produce of pig-iron in the summer months has been said to amount to fifty per cent., which, of course, is far from an average statement. That this effect is to be attributed to the increased temperature of the atmosphere, and consequent expansion of the air, there can be no doubt. One thing is certain, that during the cold winter months, when the temperature of the atmosphere is lowest, and consequently contains a larger quantity of oxygen in a given volume of air, the blast-furnaces are found to produce, with less fuel, the largest quantities of the best iron.

The quantity of air thrown into a furnace per minute, has been computed at upwards of seventeen thousand gallons, and at a pressure of two and a half, or three pounds per square inch; if, then, it be correct, as chemists have asserted, that six inches of vital air is absorbed in one minute by each individual of our species, the quantity of this element consumed by an ordinary blast-furnace, is equal to that required by 200,000 persons! It may be added here, as giving some idea of the consumption of fuel in the smelting process alone, that, according to computation, the iron-works of Carron, in Stirlingshire, burn annually as many coals as would be required by a city containing 700,000 inhabitants!

From the top of the blast-furnace, or the tunnel head, there is continually escaping a large quantity of gaseous matter, the products of the combustion going on within the furnace; and this is evolved at a very elevated temperature. Numerous attempts were made to collect this waste heat, and employ it in heating the air, and for various other purposes; but most of them were abandoned, as it was found generally disadvantageous. However, at the Ystalyfera iron-works, near Swansea, Mr. James Palmer Budd has introduced a plan, which he described to the British Association when they visited that neighbourhood, and which is found to answer exceedingly well. Mr. Budd says:—"Taking the annual produce of iron in Great Britain in round numbers to be 1,500,000 tons, or about 500,000 tons made in England, 500,000 tons in Wales and Monmouthshire, 500,000 tons in Scotland, a saving of even 1*s.* per ton on the cost of production amounts to the large sum of 75,000*l.* a year." Mr. Budd's plan is best given in his own words:—

"Fortunately, in my attempts to use the escape from the tunnel-head to heat my blast of air, I neither made my apparatus part of the furnace, nor did I attempt to burn the gases. I built my stove alongside the furnace, of which, however, it forms no part; and by means of a stack about 25 feet higher than the top of the furnace, I was enabled to draw into it as much of the heated air and flame as I required. The result of this plan has been a most perfect success, from its thorough simplicity. I interfere in no way with the operations of the furnace; everything is as before; my apparatus is merely three or four horizontal flues of about 12 in. diameter, constructed about 3 ft. below the top of the furnace, and leading into an adjoining chamber or stove, provided with a stack which makes the draught. Into this stove I am enabled to draw as much of the gaseous escape as I require, and by means of a damper on the stack as little as I choose. The quantity required to produce hot blast for a furnace is very little, not being more, as far as I can judge, than one-sixth of the quantity passing off the tunnel-head. I attempt no combustion of the gases; for as they rise from the furnace and enter the stove with a temperature of about 1800°, and leave it at a temperature of about 800°, whilst all the heat I require for the blast is about 600°, the mere passage of them as heated vapour through the stove gives me all the temperature I want."

Another portion of this heated air has been employed to heat the boiler of a steam-engine on the works with the utmost success; and by this application 35 tons of coal a week are saved in the stoves, and a similar quantity in the boilers.

There are still a few furnaces in the kingdom working with charcoal, the metal from which is generally used for iron wire, and other purposes where a very superior degree of tenacity is required. The blowing apparatus for these furnaces are propelled by water-wheels; and as charcoal can only be obtained to work the furnaces a few months in the year, the winter season is fixed upon for the purpose, as water is then plentiful: but the coke furnaces are almost universally blown by steam-engines, and except suspending the blast half an hour during the time of letting out the metal, and during unavoidable repairs, the furnace is usually worked without intermission while the hearth and the lining will endure, which is mostly about three years; and where the fire-brick and hearthstones are good, a still longer time. Commonly, the workmen pursue their usual labour on the Sabbath; and this system has been considered as indispensable. From the experiment, however, of some of the Staffordshire iron-masters, the practicability of suspending the works on that day has been demonstrated.

The quantity of metal made in one furnace, where the materials are good, will amount to forty tons per week, requiring half that weight of coal, and its own weight of limestone. Argillaceous iron ore in general produces from 25 to 30 per cent.; Cumberland ore upwards of 50 per cent.

A late iron-master, to whose notes the present treatise is much indebted, justly observes, that it is one of the interesting characteristics of chemistry, when pursued as an amusement, that it is ever exciting curiosity and genius by exhibiting its wonderful changes and effects, yet frequently withholding every apparent cause for these effects; this is peculiarly the case in smelting and making iron. The few chemists who have pursued their inquiries into the nature of iron, have lamented the almost impossibility of accurately discovering its component parts. In the dry way, that is, the way in which iron is manufactured, the heat is too intense to collect what flies off, and in the humid way, viz. with acids, the same results cannot be obtained; on this account there are few subjects in which chemistry has really made so little progress as in the smelting and conversion of iron. Dr. Colquhoun, in the treatise already referred to, has entered with great minuteness into the assay of ironstones, both in the dry and the humid methods.

The best fuel is undoubtedly charcoal; and this is known to consist almost entirely of carbon; but since it can no longer be furnished in supplies adequate to the consumption, pit-coal that contains the greatest quantity of carbon, and the least amount of sulphur, is the best adapted substitute. The component parts of pit-coal are carbon, bitumen, argillaceous earth, and pyrites, or sulphurets of iron: the proportions of these vary considerably in different kinds of coals, and but few of them are applicable to the smelting of iron. Iron ore consists of varied proportions of iron,oxygen, arsenic, argillaceous earth, sulphur, and frequently various other impurities. Limestone is principally calcareous earth ; and although some kinds are more suitable than others on account of a less quantity answering the purpose, yet the quality of the metal is rarely affected by that of the lime, its sole use being as flux, to facilitate the melting of the ore, and protect the iron from the action of the blast when in the hearth.

As these materials approach the middle of the furnace, in all probability the fusion commences ; the lime and the earthy part of the ore unite, and form a glassy cinder ; the iron receives a due proportion of carbon from the coke, and descends to the bottom, and when it has passed through the cinder, little or no change can take place, as it is not found to differ, whether it remain six or twelve hours in the hearth. The presence of sulphur in the furnace, whether from imperfectly preparing the coke or ironstone, or from a defective kind of coal, is certainly injurious to the metal ; it not only impregnates it, but deprives it of its portion of carbon.

In the processes of coking coal for the iron-works, several plans have been lately introduced for removing the sulphur from the coal. The most simple of these consists in projecting water in a shower upon the incandescent material. All persons know, that when the water in a kettle boils over into the fire, a disagreeable smell is generated. This arises from the decomposition of the water, the smell is due to hydrogen combining with the sulphur of the coal. In this way in the coking ovens, the water being decomposed, the hydrogen combines with the sulphur, and, passing off as sulphuretted hydrogen, robs the coal entirely of the deleterious ingredient. The sulphur coal of South Staffordshire, which could not be employed in the manufacture of iron previously, can now, when prepared in this way, be employed with all the advantages of charcoal.

Good metal is of a strong dark grey colour, considerably granulated, runs fluid when melted, and is understood to be highly carbonated. Bad metal is tender, light coloured, has the appearance of bell-metal, and runs thick and sluggish. The best metal is most suitable to foundery goods; but it is found by experience that metal of rather inferior quality will make as good malleable iron as the best.

The products of the processes of smelting may be divided into—

1st. *Grey cast-iron*, which, when cast into pigs, frequently presents smooth concave surfaces. It forms an excellent material for casting, but is very soft and only moderately tenacious when first obtained from the furnace.

2nd. *Mottled cast-iron*, so called from its mottled appearance; it makes excellent castings, and admits of being turned and filed, taking a good polish.

3rd. *White cast-iron*, having a lamellar fracture, and being hard and brittle. It is only employed for coarse castings, and is never used in the construction of machinery.

The following list of the prices of iron at the conclusion of the year 1852, as obtained from the price list of one of our largest iron merchants, cannot but prove of interest: —

		Per Ton. £	*s.*	*d.*
Welsh iron. —	Bar iron	4	15	0
„	Slit nail rods	5	5	0
„	Cable iron	6	10	0
„	Sheet iron	9	0	0
„	Pig-iron, cold blast	3	10	0
„	Railroad bars	5	0	0
Staffordshire iron. —	Bar iron	7	0	0
„	Slit nail rods	6	10	0
„	Cable iron	7	15	0
„	Sheet iron	8	10	0
„	„ (trebles)	11	10	0
English iron. —	Bar iron	6	5	0
„	Scrap iron	10	10	0

		Per	
		£	s.
English iron.—	Locomotive engine axles forged	15	10
„	Locomotive engine cranked axles from best scrap	65	0
Yorkshire iron.—	Low moor bars	14	0
„	Boiler plates	18	0
„	„	33	0
„	Rivet iron	15	0
„	Locomotive axles	17	0
„	„ cranked and rough forged	56	0
Scotch iron.—	Bar iron	5	5
„	Angle iron	7	0
„	Boiler plates	8	5
„	Pig-iron, No. 1.	1	18
„	Refined metal	3	10
„	Railway chairs and sleepers	4	0
„	Cast-iron lamp-posts	16	0
„	Iron pipes	4	10
„	Rails	5	5

CHAP. IV

CAST-IRON FOUNDERY.

CASTING IRON ARTICLES. — FOUNDING AND BORING CANNON. — PIPES OR CYLINDERS.—FATAL CATASTROPHE.—CAST-IRON ROAD RAILS. — BRIDGES. — SUNDERLAND BRIDGE. — SOUTHWARK BRIDGE. — CAST-IRON MASONRY. — PILLARS. — FOUNDERY GOODS.

By *casting* is meant the process of converting fusible metal into any given form, by pouring it when in a liquid state into a mould. As the separation of all metals from the ores necessarily exhibits this molten state, and as the flowing of the mass into whatever receptacle is designed to receive it must always have presented, or at least have approached, the practical illustration of the foregoing definition, it might be presumed that this method of obtaining metallic articles, so familiar in our times, had been known from the remotest antiquity. This, however, was certainly not the fact with reference to iron; and when we recollect the degree of ingenuity and experience required to mould in sand the simplest vessel, our wonder will probably be diminished.

It is, however, only to the very earliest ages, or most barbarous nations, that this remark strictly applies, for it is certain, that the art of casting in brass or bronze, as will be hereafter shown, is of very ancient origin. In considering this subject, there is one delusion to which many persons may be liable, namely, an indefinite idea that, as we possess so many articles of modern convenience, necessity, or luxury, that are formed in the casting, so might the nations of antiquity: this, however, as regards iron articles especially, is quite erroneous, nor, upon consideration, will it appear strange that such should have been the case in the infancy of knowledge.

To form a jar of clay, to bake it in the fire, and even to confer upon it some degree of symmetry or ornament, may be said to be the operations of a people elevated only one degree in the scale of civilisation; but to mould that jar in sand or clay, and then withdrawing the model to pour into the matrix a quantity of liquid metal in order to produce a casting, requires a much higher state of knowledge and experience.

At what precise period, and in what country, an art carried to such a vast extent first began to be practised, seems almost a futile inquiry. Mr. Mushet not only fixes the date of the discovery of the art of casting in iron in this country about the year 1550, but likewise considers the process to have been an English invention; at all events, it does not appear that the cast-iron trade was known among us before that period.

The first description of goods produced by the new process would, of course, be the ordinary cooking utensils in domestic use, pots and pans: these would presently be followed by ranges and ovens, and a variety of implements used in the manufacture of metals in general. At present there is hardly a single article capable of being manufactured in wrought-iron, the like of which the ingenuity of the sand-moulder cannot produce in cast metal. It does not come within the scope of the present treatise to enumerate every article for which science and commerce are now indebted to the iron-founder: among the more striking may be mentioned, those which have superseded the use of wood and stone; as frames for machinery, waggon-races, spandrils for roofs, columns, waggons, bridges, barges, churches; and the large and beautiful structures at our railway termini.

During the eighteenth century, iron-foundery became almost identified with casting of cannon. The consumption of cast-iron as well as of brass, in the article of ordnance alone, during our wars in Belgium, with America, and arising out of the French revolution, was beyond all conception enormous. This branch of home trade, having government for its especial patron, enriched many individuals, who, if a pun might be allowed, may be said to have become *founders* of families as well as of guns. Of this class may be mentioned the respectable house of Walker, at Masbrough, near Rotherham, where this business was for many years carried on with unprecedented success.

Some idea of the quantity of cast-iron which at one period was consumed in the article of guns, &c. may be formed from the fact that, about 1795, the average amount of metal purchased by the board of ordnance in the state of cannons, mortars, carronades, shot and shells, taking the account of three years, was estimated at nearly 11,000 tons annually. The India company took for a yearly supply about half of that amount, i.e. 5000 or 6000 tons; and besides these two items, other armed trading vessels were said to purchase 10,000 tons, making a total of 26,000 tons of iron annually cast into that "devilish enginery," at the explosion of which, so oft, by sea and land, a few years ago,

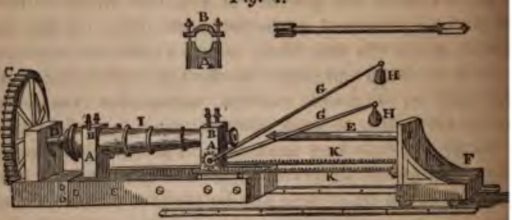
> "Immediate in a flame,
> But soon obscured with smoke, all Heaven appear'd,
> From those deep-throated engines belch'd, whose roar
> Embowell'd with outrageous noise the air,
> And all her entrails tore, disgorging foul
> Their devilish glut, chain'd thunderbolts and hail
> Of iron globes: which on the opposing host
> Levell'd, with such impetuous fury smote,
> That whom they hit, none on their feet might stand,
> Though standing else as rocks, but down they fell
> By thousands."
>
> *Par. Lost*, b. vi. 584—594.

Cannon are cast from wooden models, which have been exactly and smoothly turned at a lathe, so that they may leave the sand with facility during the process of moulding; and as the model does not admit of being drawn from the sand like a smooth cylinder, they are moulded in boxes opening along the sides. The metal is required to be of the best quality, and along with the common sort, it is usual to mix the superior Welsh pig, and that drawn from the rich ores of Cumberland.

As the pieces are generally bored on the premises where they are cast, a description of that process, as practised at Masbrough, may not be uninteresting in this place.

Every gun, previous to its being bored, is fixed in stout iron frame between two centre points, and engine turned all over the outside with sharp steel tools properly fashioned. It is then carried to the boring engin (*fig.* 4.), and placed horizontally in two massy cast-iro

Fig. 4.



supports, A, A, each containing a hollowed brass gull exactly fitting to the gun at the breech and at the nec and over which the collar B is screwed down, that th piece may revolve steadily. It is then connected wit the cog-wheel C by means of a square iron box at I a square knob of a corresponding size being cast upo the breech of the cannon for this purpose, but which ultimately cut off. The sharp steel drill E is the brought into contact with the muzzle of the gun, b advancing the carriage F, the front of which, bearing th borer, is a massy metal plate, strengthened by bracke from behind, and resting upon a cube of solid iron abou nine feet square and twelve inches thick, and whic moves on small truck wheels along a metal road. Upo the square projecting axles of the cog-wheels on eithe side of the supports are next placed the levers G, G, an upon these the weights H, H; the gun I is then mad to revolve slowly by putting in motion the wheel C From the sketch it will be obvious, that when the dri is brought into contact with the piece to be bored, an the latter turned round by the machinery, the effect o the levers through the operation of the pinions upon th two racks K, K, must be, by maintaining a constant pres sure, to keep the drill to its work; the levers, meanwhile, as their weights respectively approach the floor, being taken off and replaced at their first elevation till the boring is completed; and which, in a thirty-eight pounder, will generally require about forty-eight hours, including two or three stoppages to sharpen the drill. The racks are about twelve feet long, and the other parts of the machinery in proportion; the whole being exceedingly massy, and firmly bound together.

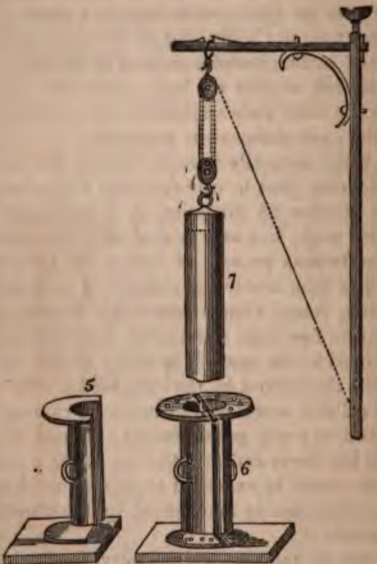
When the gun has been bored to the proper depth by this process, the drill is removed, and another instrument introduced into its place consisting of a shaft of iron shod at the extremity with four or five square bits of steel, attached by longitudinal grooves to the rod. This being introduced, widens the bore about the eighth of an inch, at the same time smoothing and perfecting the calibre to the exact dimensions required.

An idea must naturally present itself to the most indifferent observer, that to cast the guns hollow at once, as it would involve no difficulty, so it would not only facilitate the work, but save a deal of expense consequent on the tedious process of boring the solid metal. This plan has been tried, but abandoned as unsatisfactory; it being found almost impossible thereby to get the inside quite free from flaws; and, as every piece was not only proved at the arsenal, by firing double charges, but examined throughout by the introduction of a spring instrument called a *searcher*, the core-cast cannon were rejected. Indeed it will be universally admitted, without adverting to the direct and dreadful use of the guns, that too great care cannot be exercised to prevent artillerymen from being unnecessarily endangered by the bursting of imperfect metal.

Happily for the interests of humanity, the business of cannon-casting on the large scale appears to be at an end; the foundery being at present at work chiefly for the arts of peace. Since the introduction of gas, the demand for cast-iron piping has increased amazingly; and it is gratifying thus to reflect that much of the metal which, under other circumstances, might have composed a "devilish enginery" for carrying death through ranks of our fellow-men, is now used for the economical conveyance of the pabulum of illumination through our towns, manufactories, and dwelling-houses, and most extensively for conveying water into cities from distant reservoirs.

In casting these pipes boxes or cases are used, consisting of stout metal cylinders, about three feet in length, and formed of halves, as represented by *fig.* 5. Two of these being placed together, and fastened at the flanges along the suture with iron cramps, and fixed exactly upon a firm foundation, form the case, *fig.* 6. The smooth maundril, *fig.* 7., answering to the outside of the pipe to be

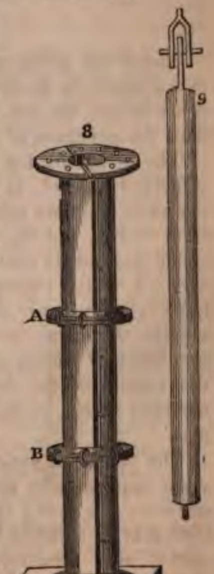
Figs. 5, 6, 7.



then lowered perpendicularly down the centre ase till it rests in a hole in the stand at the bot- ing in the next place made firm at the top by a ance which keeps it equidistant from every part inner circumference. The interval around the il is then filled up with sand, properly sifted and ed, and which is continually supplied and rammed ntil it reaches the mouth of the box. The maun- hen carefully drawn out by means of a windlass, sand-charged cylinder is removed to the drying Three or more of these cylinders, according to gth required, are used in casting a pipe.

e next place, the moulder quadrangular rod of iron, foot longer than the in- pipe, and this, after being rapped all along with a and, is inserted within a de quite smooth inside; filled with sand-mortar of r consistency, and made e by the addition of loam, ung, and hair. This *core*, called, being drawn from e, is placed on a rack a fire till sufficiently dry sed with safety and suc- When the workmen are o cast a pipe, generally ine feet in length, three sand boxes, prepared as described, are taken and one upon the other in a pit, fastened together by cot- sing through correspond- es in the circular flanges, *ig.* 8. The before-men- sand core, *fig.* 9., is then y suspended and let down

Figs. 8, 9.



the aperture, until its lower extremity falls into a centre socket at the bottom; while at the upper end it is adjusted to the centre by a collar of clay. It will be plain from this description, that the space between the outside of this sand pillar and the inside of the surrounding mould, represents the actual strength of the pipe intended to be cast. When all the arrangements are completed, a sufficient quantity of the liquid metal is suffered to flow from the furnace into a pan fastened into an iron frame, so as to be carried by three or four men, and its contents poured into a mould by an orifice at the top.

Fig. 10.

Should the quantity of metal required to be carried to a distance in the foundery be too heavy to be lifted in this manner, the pot is carried on a drug, and poured with the assistance of pullies.

The mould having received the metal, and become sufficiently cooled, is altogether hoisted from the pit; the outer cases are taken off, the iron rod is withdrawn from within, and the pipe being cleared from the sand inside and out, is ready for examination, dressing, and use. A similar course is pursued in the casting of very large cylinders, only that in these, and in similar heavy articles, the metal, instead of being carried in a vessel, is conducted by means of a trench of sand directly from the mouth of the furnace to the pit containing the moulded article, in the same manner as in casting metal pigs.

The casting of various solid articles which from their shape require to be moulded in boxes, is conducted on the same principle: it was during an operation of this kind that an accident happened at the Thorncliffe iron-works, near Barnsley, presenting phenomena at once singular and awful. On the 19th of July, 1820, during a tremendous thunder-storm, a number of workmen and boys belonging to the works, together with the acting partners and managers, altogether more than one hundred persons, were assembled in the casting-house, as was customary when anything particular was about to be cast, for the purpose of witnessing the casting of a tilt-shaft, about five tons weight, in a perpendicular mould. When the casting was nearly complete, the liquid mass suddenly shot up like a cataract of molten lava from the orifice of a volcano, and, mingled with clouds of heated sand, fell in red-hot flakes on every side. Of the persons present twenty-two were burnt more or less severely, three perished on the spot, and six others died in a few days! The immediate cause of the catastrophe could not be satisfactorily ascertained. Happily, occurrences of this sort are exceedingly rare: that, at the place in question, formed the only instance of an accident having taken place during twenty-five years.

The pigs, into which the metal is cast immediately on its flowing from the furnace, are moulded with wooden patterns in the sand on the floor, the metal being allowed to find its own level, as if it were water in a canal and its branches. In a somewhat similar manner are cast many articles of great weight, and of a form calculated to leave the sand on being lifted horizontally from the floor. The model of a floor joist, or a road rail having been thus imbedded in the sand, and a superior level of the bed and the surface of the article established with a plumb line, the model is lifted from its bed with a crane, and the impression or mould carefully examined with the assistance of a candle or a mirror: any bits of sand are taken out by means of a loop of iron, and any holes stopped with a small trowel. The gutter, or other impression, being by these means thoroughly cleared and perfected, a level cover of sand compressed into a frame is then placed over it, and weights laid upon it to keep it firm, after which the metal is conducted to the mould by a trench as usual.

The use of cast-iron rail courses for wheel carriages, and which at this time is becoming so vastly important in connection with locomotive steam-engines, appears first to have obtained, to any considerable extent, in the neighbourhood of Newcastle-upon-Tyne, about the year 1797. It has been proved, however, that at least six tons of rails, intended as an experiment, were cast at the Colebrook Dale works, on the 13th of November, 1767; and at latest in less than within ten years from the last-mentioned date, Mr. Curr introduced these rails to a considerable extent in the duke of Norfolk's collieries, at Sheffield This was the plate rail, which consisted simply of a rail about seven feet long, cast in the form of two plates forming a right angle at their juncture, each part being three or four inches wide; these rails were laid so that their ends met upon a wooden sleeper, laid across the road, and supported upon large stones; upon this sleeper the ends in contact were nailed down. In the annexed sketch, *fig.* 11., *a a* indicate a sectional view of the first and simple form of those cast-iron rails, the introduction of which has led to such stupendous results in the construction of metal roads for inland carriage. In the chapter which embraces the particular consideration of rails, much information on those now employed will be found.

Fig. 11.

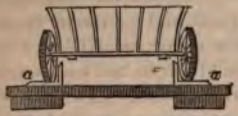
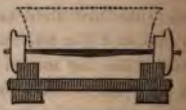


Fig. 12.



Of course, the form of this rail has undergone various alterations; the most material consisted in dispensing with the upright sides altogether. This mode, which was found to diminish the friction to a considerable amount, arose out of an alteration in the form of the wheels of the waggon: the rail being reduced to a square rod, the circumference of the wheel was cast with a flange, projecting sufficiently to keep the rail without biting much upon it. This improvement will be clearly understood by the section, *fig.* 12.

Towards the latter end of the last century the public began to be surprised by the appropriation of cast-iron to a novel and magnificent purpose—the construction of bridges. Several works of this kind were undertaken with success, and the lightness and elegance of the fabric, as well as its singularity, became the theme of universal discussion and curiosity.

The credit of having first suggested the practicability of constructing bridges of cast-iron, has been claimed for Thomas Paine, who is said to have conceived the idea from contemplating the fabrication of a spider's web in America. Whatever may be thought of this assertion, it is certain that, in 1787, Paine presented to the academy of sciences at Paris the model of a bridge which he had invented; and it is equally a fact, that during the greater part of the year following he resided at Rotherham, in Yorkshire, where a bridge, chiefly of wrought iron, was constructed, under his direction, by the Messrs. Walker. Whatever may have been the precise principle of this pattern bridge, it was taken to London; exhibited there for a time; returned again to Rotherham, and there broken up. Pieces of this fabric were not long since to be seen on the premises of Messrs. Walker! It appears, however, from designs now or lately in the possession of Mr. White of Devonshire Place, that Mr. Pritchard, an architect of Eyton Turret, Shropshire, so early as the year 1773, suggested the practicability of constructing wide iron arches, capable of admitting the passage of the water of such a river as the Severn; and, in fact, the first practical exhibition of the plan, on a large scale, was the construction of the bridge at Colebrook Dale, chiefly in accordance with Mr. Pritchard's plans.

In 1790, Rowland Burdon conceived the idea of throwing an arch of cast-iron over the river Wear, at Sunderland; for which, two years afterwards, and after surmounting some opposition, he obtained an act of parliament. The use of iron had previously been introduced in the construction of the arch at Colebrook Dale.

Mr. Burdon's plan consisted in retaining, together w
the metallic material, the usual form and principles
the stone arch, by the subdivision of the iron into bloc
answering to the keystones of a common arch. Th
blocks were of cast-iron, five feet in depth and four
thickness, connected together by bars and cottars
wrought iron. The entire structure consists of
ribs, each containing 105 of these blocks, abutting
each other like the voussoirs of a stone arch. The
are six feet distant from each other, braced together
hollow tubes and bridles of cast-iron. The whole wei
of the iron is 260 tons; 46 malleable, and 214 c
The arch is the segment of a large circle, of which
chord or span is 236 feet. This magnificent str
ture, which was executed at the foundery of
Messrs. Walker of Rotherham, was completed wit
three years; Mr. Thomas Wilson, of Bishop W
mouth, being the architect. This bridge was, at
time of its erection, considered to be the largest arc
the world; and being placed, too, at a considerable
vation above the river, it forms a remarkably
turesque object. The whole expense of the un
taking was 26,000*l.*, of which sum 22,000*l.* was
scribed by Mr. Burdon, the original projector.
famous bridge was, in October, 1816, disposed of
lottery, consisting of 6000 tickets; and 150 prizes,
the value of from 100*l.* to 5000*l.*, to the total amo
of 30,000*l.*

About forty years afterwards, a still greater achie
ment in cast-iron was exhibited in the metropolis.
was Southwark bridge of three arches, constructed
the river Thames, and which was likewise execute
the foundery at Rotherham, the first casting hav
been run on new year's day, 1815; the whole of
articles, including of course the models, occupy
about two years in the execution. The engineer
John Rennie, Esq., who originally intended that
outer plating of the centre arch should have been
vided into seven segments instead of thirteen, its pres

number. The practical difficulty of casting such immense pieces, however, led to the adoption of the arrangement which the structure now exhibits. These plates, being too large to be covered with boxes in the manner of other similar castings, were moulded in "open sand;" that is, the models, after being sufficiently impressed upon the sand, were removed, and the metal suffered to flow into its bed, the surface being merely formed by the level of the molten lake. The erection of this wonderful triumph of foundery ingenuity occupied about two years, and the bridge was opened to the public on the 25th of March, 1819. Its weight and dimensions are as follow:—

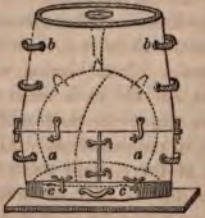
Span of the centre arch	240 feet.
Rise of the springing	24 feet.
Span of the two side arches	210 feet each.
Piers	24 feet thick.
Width of the roadway	28 feet.
Width of the footpaths	7 feet each.
Weight of metal in centre arch	1665 tons.
Weight in two side arches	2920 tons.
	4585 tons.

In 1827, Mr. Deeble, a metropolitan engineer, obtained a patent for an ingenious method of casting metal blocks for the purpose of forming caissons, jetties, piers, quays, embankments, lighthouses, foundations, walls, or other such erections. These blocks, which are hollow cases, so cast as to fit into each other by grooves and dovetails, and other contrivances, would form masses of exceeding strength in combination. There is, however, one fatal objection to their adoption in situations where they might be most useful: the sea water, by some unexplained process, so alters the nature of cast-iron, that its cohesion appears to be quite destroyed. Cannon, after lying long in the sea, have been found converted through their substance into something resembling plumbago, and admitting of being cut with a knife. This was particularly the case with the iron guns of the Royal George which went down off Spithead.

Among the architectural purposes to which cast-iron has already been most successfully applied, may be mentioned pillars, as well fluted as plain, for the support of galleries in houses, the roofs of our railway structures, and numerous other edifices. Those who have paid any attention to the cumbrous, unsightly columns which occupy so much space, and so obstruct the view in most old churches, must perceive at once the beauty and utility of the light and elegant metal shafts which have so generally superseded them.

At most of the iron founderies pots or posnets are cast; and, as the method of moulding these articles is, though simple, yet curious, it will not be out of place to describe the process. The model of the pot, say of the capacity of five gallons, is made of brass, smoothly turned inside and out, and about three sixteenths of an inch thick; it is then cut into two parts in the line of an axis from the centre of its mouth. The moulder takes these two hemispheres, and places them together mouth downward upon a circular board, having a bevel edge turned just to fit the mouth or expanding flange of the pot: he then places over the whole a box *a* (*fig.* 13.), consisting of a strong iron hoop divisible into two parts by means of hasps and staples at the sutures, where there are internal projections for retaining the sand and facilitating the opening of the box laterally. Around the

Fig. 13.



model thus placed, sand of a proper consistency is rammed down till the box be full, that is, reaching to the equator of the pot. The surface of this sand being made smooth, and well powdered with dry, burnt, pounded stone, the box *b* is placed upon the first mentioned, these being attached by suitable pegs and ears projecting from the boxes respectively: into this, as into the former box, sand is shovelled and well rammed about the model until it reaches the bottom (which, it will be recollected, is now uppermost in the process). Models of the feet, and likewise of a taper core from the centre, are now placed upon the bottom of the pot, and carefully settled in their places by means of being surrounded with sand, with which the box is now filled up, and having been levelled with a strickle, is turned over upon a board in a contrary position to that in which it appears in the engraving; when, on the removal of the circular board first mentioned, it is evident that the inside of the pot must be completely exposed. The next process is to place the third box *c* (seen undermost in the figure) upon the one heretofore uppermost in the moulding; and to fill the inside of the pot and the box together, with sand well rammed in and levelled on the superior surface, as in the former box. The whole is now again turned over, when it stands as represented in the cut. It will now be seen, that by loosing all the hasps the upper box may be lifted off by the handles, and the lower one drawn away laterally in two halves, by which means the brass model will be completely exposed, and may be easily removed by its separation at the line of contact of the two pieces: the feet and the core at the bottom are likewise taken out of the sand. The concave and convex parts of the matrix are now smoothed all over with properly formed bits of bright metal; after this the whole is dredged with bean flour, and upon that a considerable dusting of powdered charcoal is shaken from a bag. The whole is once more made perfectly smooth by the tools of the moulder, who performs this delicate operation with surprising dexterity. The different parts of the mould being carefully re-attached in the position shown by the figure, the metal is poured in at the hole at the top; and by burning away the meal and the charcoal, the casting comes out of the sand perfectly smooth and clean. *Fig.* 14. represents the boxes used for casting kettles and pans of the well known shape indicated by the dotted lines; these are cast of the best metal, are much lighter than the former, and are generally tinned inside: the chief founderies for this description of utensils are at Birmingham and Leeds. *Fig.* 15. represents an iron pot or boiler, which consisting as it does of the frustrum of a hollow cone, the model does not require to be cut, and only two boxes are required for the moulding, as the model will draw out of the sand in the one, and of the core on the other without difficulty.

Fig. 14.

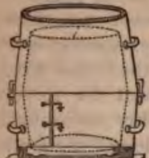
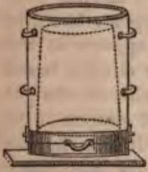


Fig. 15.



The methods of casting, annealing, and tinning this kind of pans, more particularly those with oval bellies, formed the subject of a patent granted in 1779 to a person of the name of Taylor, of Birmingham. They are, as already stated, cast by a process in all respects similar to that employed in the casting of the metal pots just described; but instead of being sold from the sand, they are still further finished by annealing and tinning: the former of these processes is performed by enclosing the article in a cast-metal pan, and covering it therein with coal dust or ashes, so as to exclude the air as much as possible; the whole is then surrounded by fire till the pot is reduced to a sufficient softness, which is generally in about twenty-four hours. The turning of the elliptical pots is performed by affixing them in a large chuck upon an oval engine or lathe, and operating on the inside with steel chisels: the round ones are turned by a similar method in the round lathe. The tinning and finishing is performed by holding the pot to be tinned over the fire till it becomes of a regular proper heat to receive the tin; when a proper quantity of grain tin, mixed with sal ammoniac, is put into it, the pot being still kept over the fire, and the tin worked about with sal ammoniac till it takes and adheres to the pot in the proper amount and manner. A quantity of melted tin is then dashed upon the surface, a sufficient portion of which adheres to constitute the lining; the superfluous metal is then turned out, and the vessel immersed, mouth downward, in cold water to set the tin, which by this means is done without the water coming into contact with the tin while in a fluid state. As any contact between the water and the tin, while the latter is in a fluid state, will cause it to fly off more or less, and thus injure the work, this method of cooling cannot be successfully adopted with vessels that require to be tinned inside and out. In performing the operation under the latter circumstances, instead of dipping in water, the vessel is quickly withdrawn from the melted tin and exposed to the action of a rapid current of cool air, which current is produced either by means of a pair of bellows, or by a draft occasioned by a high chimney. More complex apparatus were invented, and a patent obtained for cooling by this method, by a person of the name of Kenrick, about ten years since.

It would be as tedious as unprofitable to describe in detail the methods adopted in the production of that endless variety of smaller and generally useful articles, denominated *foundery goods*. These are mostly moulded in boxes of all sizes, connected in the middle by means of iron fastenings, and filled with *green sand*, as that used in moist casting, in contradistinction to dry, is termed by the workmen.

Iron and, indeed, metallic castings in general are said to be much improved by subjecting the metal, as soon as poured into the moulds, to pressure: this is done by making a part of the mould of such a form as to receive a piston, which, on the metal being introduced, is made to press on it with any required force. It has been stated that castings treated in this manner are not only free from the imperfections generally incurred by the usual mode, but have likewise a peculiar soundness of surface and closeness of texture; qualities of the utmost importance in ordnance, rolling cylinders, and many other articles. Whatever may be the merits of this plan, however, the inconvenience attending its application to common sand-casting will prevent it from becoming general. The same objection will apply with still greater force against the more complex peculiarity introduced into the mode of casting cylinders by Mr. Church of Birmingham, and which aims at similar desiderata, namely, to produce articles "free from air-holes, perfectly sound, compact, and of a uniform texture," or even with a case-hardened surface. This invention, for which a patent was obtained, consists in exhausting the mould of its atmospheric air by means of a pump, and then forcing the metal *upward* into the mould by a similar process.

It is not uncommon to *case-harden* railroad plates by casting them upon a piece of cold iron: this method, termed *chilling*, is more especially resorted to in the casting of cylinders for rolling metal, forge hammer faces, and common stithies.

Practical engineers, architects, and others, who have occasion to calculate to any degree of nicety to what extent economy and safety may be combined in the use of iron in a large way, will find rules and tables admirably adapted to assist their inquiries in Tredgold's "Practical Essay on the Strength of Cast Iron and other Materials." In that work will be found an ample series of experiments on the resistance to compression and impulsion, tension, torsion, stiffness, tenacity, &c.

The following remarks, to the conclusion of the section, are mostly in the words of this intelligent author. The two most obvious varieties of cast-iron are the soft grey and the white kinds. Metal of the former sort yields easily to the file when the external crust is removed, and is slightly malleable in a cold state. Dr. C. Hutton has justly given the preference to such iron, because it is "less liable to fracture by a blow or shock than the hard metal."

White cast-iron is less subject to be destroyed by rusting than the grey kind, and it is also less soluble in acids; therefore it may be usefully employed where hardness is necessary, and where brittleness is not a defect: but it should not be chosen where strength is necessary. When it is cast smooth it makes excellent bearings for gudgeons or pivots to run upon; and is very durable, having little friction.

White cast-iron in a recent fracture has a white and radiated appearance, indicating a crystalline structure; it is very brittle and hard, a file having little or no effect upon it.

Grey cast-iron has a granulated fracture of a grey colour with some metallic lustre; it is much softer and tougher than the white cast-iron.

But between these kinds there are varieties of cast-iron, possessing divers proportions of these qualities; those should be in general esteemed the best which approach nearest to the grey cast-iron.

The best grey cast-iron is used for artillery, and is sometimes on that account called gun metal.

A familiar test of the quality of a piece of cast-iron is to try the edge with a hammer: if the blow of the hammer make a slight impression, denoting some degree of malleability, the iron may be presumed to be of a good quality, provided it be uniform; if fragments fly off, and no sensible indentation be made, the iron will be hard and brittle.

The utmost care should be employed to render the iron in each casting of a uniform quality, because in iron of different sorts the shrinkage is different, which causes an unequal tension among the parts of the metal, impairs its strength, and renders it liable to sudden and unexpected fractures. When the texture is not uniform, the surface of the casting is usually uneven, where it ought to have been even. This unevenness, or the irregular swells and hollows on the surface of a casting, is caused by the unequal shrinkage of the different qualities of the iron. Founders of experience and observation are well acquainted with this test of an imperfect casting.

Now when iron of particular quality is obtained by mixture of different kinds, it will be difficult to blend them so thoroughly as to render the product perfectly uniform: hence we easily perceive one reason of iron being improved by annealing; for in passing slowly to the solid state, the parts are more at liberty to adjust themselves, so as to equalise, if not neutralise, the tension produced by shrinking. But it must be clear that an annealing heat, applied after the metal has once acquired its solid state, must be sufficiently intense to reduce the cohesive power in a very considerable degree, otherwise it will not be sensibly beneficial.

Banks has remarked, that "iron varies in strength, and not only from different furnaces, but also from the same furnace and the same melting; but this seems to be owing to some imperfection in the casting, and in general iron is much more uniform than wood." The very great strains, however, which large masses of well-mixed cast-iron will bear when applied to resist the greatest stresses in mill and engine work is now extremely well known in this country. Its value was foreseen by our celebrated Smeaton at an early period of his practice. Upwards of fifty years ago, he combated the prejudices against it in the following language:—"If the length of time of the use of these (cast-iron) utensils is not thought sufficient, I must add, that in the year 1755, that is, twenty-seven years ago, for the first time I applied them as totally new subjects, and the cry then was, that if the strongest timbers are not able for any great length of time to resist the action of the powers, what must happen from the brittleness of cast-iron? It is sufficient to say, that not only these very pieces of cast-iron are still at work, but that the good effect has in the north of England, where first applied, drawn them into common use, and I never heard of one failing." These remarks were written in 1782; and the good opinion of Smeaton has been fully justified by the experience of succeeding engineers: the grand and varied works of Wilson, Rennie, Boulton and Watt, Telford, &c., abundantly confirm it.

To this enumeration it is right to add the name of Tredgold, whose remarks conclude as follows:—"Yet I must not omit to remark, that cast-iron, when it fails, gives no warning of the approaching fracture, which is its chief defect when employed to sustain weights and moving forces; therefore care should be taken to give it sufficient strength; and it will be obvious, from the preceding remarks, how much its strength depends upon the skill and experience of the founder. The parts of each casting should be kept as nearly of the same bulk as possible, in order that they may all cool at the same rate. Great care should be taken to prevent air bubbles in castings; and the more time there can be allowed for cooling the better, because the iron will be tougher than when cooled rapidly: slow cooling answers the same purpose as annealing. In making patterns for cast-iron, an allowance of about one eighth of an inch per foot must be allowed for the contraction of the metal in cooling; also the patterns that require it should be slightly bevelled to allow of their being drawn out of the sand without injuring the impression: about one sixteenth of an inch in six inches is sufficient for this purpose."

It may serve still further to exhibit the progress and importance of a staple of such immense advantage to the commerce and manufactures of Great Britain, if we give below a few items which were published by the jurors in their report on the metal manufactures of 1851.

The quantity of cast-iron produced in England is as follows:—

	Tons.
In 1836 - - - -	1,000,000
1840 - - - -	1,396,000
1844 - - - -	1,210,000
1845 - - - -	1,512,500

In the following years, owing to certain important fiscal alterations, the trade received a great stimulus and the make rose—

	Tons.
In 1848 to - - - -	1,998,568
1849 - - - -	2,000,000
1850 - - - -	2,250,000,

and in 1851 to an amount probably more than double the quantity made in 1844, seven years previously.

The quantity of coal raised in 1840 is not accurately known, but in 1850 it is estimated at 34,750,000 tons. The increase must have accompanied that of the make of iron, of which it is one of the most essential elements. The average price of coal at the pit's mouth in England is estimated at 5*s.* 7*d.*, and that of pig-iron at 48*s.* The produce of these two branches of industry amounts, therefore, to the annual value of upwards of 15,000,000*l.*;

viz., 34,750,000 tons of coal, at 5*s.* 7*d.* per ton -	£9,701,000
2,250,000 tons of pig-iron, at 48*s.* „ -	5,400,000
	£15,101,000

Of this vast production, about one half the iron and one fourth part of the coal are exported to the colonies or to foreign countries. In 1852, the Messrs. Blackwell, of the Russell Hall iron-works, determined that the quantity of coal raised in South Staffordshire was about 5,500,000 tons, the present value of which may be taken at about 2,500,000*l.* The quantity of coal required for calcining and for smelting the iron ore, is at the rate of about three tons for one ton of pig-iron, or about 1,950,000 tons annually for this purpose.

The average production of iron from the clay iron stone ore of South Staffordshire is about 33 per cent. The quantity of pig-iron produced is 650,000 tons, which ember, 1852) may be valued at about 3,000,000*l.* quantity of bar iron made is at the rate of 500,000 per annum, the value of which, in consequence of late great advance in the price of iron, may be estited at 5,500,000*l.* The number of furnaces (1853) w in blast are 129, while 30 only are out of blast. he number of mills and furnaces now at work in South taffordshire alone are 1469.

The following information obtained from the report of M. Dufrenoy on the iron manufacture of France, is of much importance in the history of metal manufacture.

The ores of iron are particularly abundant in the middle tertiary deposits which cover the elevated plains of Champagne and Berry. Much iron still continues to be made with charcoal, some with a mixture of coal and charcoal, and a considerable quantity with coal alone. This latter method, while lowering the price, has also given a great development to the manufacture of pig and wrought iron. In 1819, the produce of iron in France was 112,000 tons, in 1845 it reached 522,385 tons. It appears from statements made in the annual report of the corps des mines, that the three countries in Europe next in order to France in the manufacture of iron are Russia, Sweden, and Prussia, and that the make of the first, from 1835 to 1838, was 189,000 tons of pig; of the second, in 1839, 115,000 tons; and of the third, in 1840, 112,000 tons. The average in France of the three years, 1835 to 1838, was 239,000 tons; in 1839, 305,000 tons; and in 1840, 348,000 tons. The quantities of pig-iron manufactured in France with coke and charcoal—

Years.	With Coke. Tons.	With Charcoal. Tons.	Total. Tons.
1819	2,000	110,500	112,500
1830	27,103	239,258	266,361
1840	77,063	270,710	347,773
1846	239,702	282,683	522,385

The quantities of wrought iron made with coal and charcoal are as follows:—

Years.	With Coal. Tons.	With Charcoal. Tons.	Total. Tons.
1819	1,000	73,200	74,200
1835	101,380	108,159	209,530
1838	115,110	109,085	224,195
1846	254,325	105,865	360,190

The annual quantity of iron manufactured in the United States is estimated at 400,000 tons. This quantity is the produce of about 298 furnaces, which are in constant operation: 57 are anthracite furnaces, and make on the average 50 tons each per week; 7 are bituminous coal furnaces, and make 22 tons each per week; 4 are coke furnaces, and make 48 tons each per week; 85 are charcoal furnaces (hot blast), and make 21 tons each per week; 145 are charcoal furnaces (cold blast), and make 14 tons each per week.

CHAP. V.

IRON. — PUDDLING. — THE FORGE.

UNIVERSAL VALUE OF IRON. — CONJECTURES AS TO THE FIRST METHOD OF OBTAINING MALLEABLE IRON. — PROCESS FORMERLY PURSUED AT CUCKFIELD, IN SUSSEX. — IN SWEDEN AND RUSSIA. — INTRODUCTION AND SUCCESS OF PUDDLING IN ENGLAND. — THE OLD IRON FORGE. — THE METAL HELVE.

Of all the mineral products, iron is of the most extensive applicability in the arts, the conveniences, and elegancies of life. "It is the possession of iron," says Gisborne, "which constitutes, humanly speaking, the difference between savage life and civil society. Its value is instantly discerned even when the eye is but half opening, and the mind but half awakening, from the night and torpor of barbarism. When a ship on a voyage of discovery touches at a new island, what, among the productions of an unknown hemisphere laid before the wondering native, are speedily the objects of his most intense solicitude? A hatchet, an adze, or a nail; a piece of broken iron, of which he knows only that it is iron, and has not yet thought of a purpose to which it may be applied. But he knows that it is iron, and that is sufficient. In civilised life, the same metal, which the Deity has mercifully provided in larger abundance than any or than all of the rest, maintains, under its varied states and capabilities, a decided pre-eminence in utility."

It has already been observed, that a knowledge of the art of working in iron with the hammer in reality preceded all application of the ingenious and now common method of casting articles in sand with the metal in its first or liquid state. We shall be the less surprised at this, when we recollect, that in the infancy of the art of iron-making it is not to be supposed that the metal, before it could be subjected to the hammer, underwent the variety of processes to which it is submitted in our more modern bloomaries, nor even that it was required to be cast into sows at all.

It has been supposed that the ore, or ironstone, which might be of the richest quality, would be laid in a hollow bed of burnt wood or ashes, in such a situation as to be exposed to the action of the wind, or of rude bellows, and then smelted, by keeping up with a plentiful supply of fuel the fiercest heat possible. The lumps of metal picked up at the end of the operation would again be placed in the same bed or furnace and re-melted, the founder from time to time agitating the mass with his stick, by which motion of its particles its fusible part, carbonic acid gas, would be disengaged. When he could no longer stir it, and it was perceived to become clammy and stiff, it would in all likelihood be rolled from the fire upon a large stone, and then, while it retained its heat, be beaten with stones or other lumps of metal, which process would drive out the particles which hindered its cohesion. By re-heating it, for it would now no longer melt, and repeatedly battering it, the lump would improve in quality, till it became perfectly malleable iron. Such a process as this is now practised by the natives in India, but they only obtain about one eighth of the iron which is contained in the ores they employ.

The description of the method of smelting the ore, and running the metal into pigs, at the old Sussex works, as detailed by Ray, has already been given. The following account of working the iron at the forge at Cuckfield is from the same author:—

"In every forge or hammer there are two fires at least; the one they call the *finery*, the other the *chafery*.

"At the finery, by working of the hammer, they bring it into bloom and *anconies*, thus:—

"The sow at first they roll into the fire, and melt off a piece of about three fourths of a hundred weight, which, so soon as it is broken off, is called a *loop*.

"This loop they take out with their shingling tongs, and beat it with iron sledges upon an iron plate near the fire, that so it may not fall in pieces, but be in a capacity to be carried under the hammer. Under which they then remove it, and drawing a little water (upon the water wheel) beat it with the hammer very gently, which forces cinder and dross out of the matter; afterwards by degrees drawing more water, they beat it thicker and stronger till they bring it to a *bloom*, which is a four-square mass of about two feet long. This operation they call *shingling the loop*.

"This done they immediately return it to the *finery* again, and after two or three heats and working they bring it to an *ancony*, the figure whereof is in the middle, a bar about three feet long, of that shape they intend the whole bar to be made of it; at both ends a square piece left rough to be wrought at the *chafery*.

"*Note*. At the *finery* three loads of the biggest coals (of wood) go to make one ton of iron.

"At the *chafery* they only draw out the two ends suitable to what was drawn out at the *finery* in the middle, and so finish the bar.

"*Note* 1. One load of the smaller coals will draw out one ton of iron at the *chafery*.

"2. They expect that one man and a boy at the *finery* should make two tons of iron in a week; two men at the chafery should take up, *i. e.* make or work, five or six tons in a week.

"3. If into the hearth where they work the iron sows (whether the *chafery* or the *finery*) you cast upon the iron a piece of brass, it will hinder the metal from working, causing it to spatter about, so that it cannot be brought into a solid piece."

The foregoing paragraphs describe succinctly the process of making iron at the various works in this country, until the introduction of the use of pit coal; and the practice abroad is pretty similar to this day. All the iron manufactured in Sweden and Russia, so far as we know, is converted with charcoal, and generally in the following manner: — They have what we term a finery; this is a sort of trough, the bottom and sides made of metal plates three or four inches thick, its length about three feet, thirty inches wide, and one foot deep. The blast is introduced on one side and near the top, through a pipe with a bore of an inch and a half diameter. This vessel being partially filled with charcoal, fire is applied, and excited by the blast; as much pig metal is then placed upon the fire as will make one bar, and covered over with additional charcoal. When the metal becomes melted, the workmen continually stir it about with large pokers or iron levers, and submit it as much as possible to the action of the blast, by which means the oxygen contained in the air deprives the metal of its carbon, and it becomes malleable iron. As it gradually approaches this state it has a strong tendency to unite and become one mass: when this is sufficiently the case, it is raised to the top of the fire, and with a large pair of tongs taken and put under the forge hammer, where it is consolidated by gentle strokes. It is then passed through another fire or chafery similar to the former, and by repeated heating and forging it is reduced to the state of a bar such as we receive it.

In England, however, when, about a century ago, the use of coke began generally to supersede that of charcoal, it was found expedient, on account of the inferiority of the fossil fuel, to take the iron from the chafery in smaller pieces, and beat them under the hammer into cakes about an inch thick; these when cold are broken into fragments about two inches square, and piled in a sort of obtuse cone, upon a round flat slate, about nine inches diameter, each ball being sufficient to make one bar. Eight or ten of these are then placed in a reverberating furnace previously brought to an intense heat;

when the iron has attained a welding glow, the balls are alternately drawn forth with tongs, and the forgeman being ready with a staff or bar of iron, with the end heated welding hot, he lays it upon the ball under the hammer, and with a dexterity which appears extraordinary to a bystander, turns and forms the lump into the shape required. If it be for bar-iron, he forms the middle of the piece into the proper size; the ends being reheated in the chafery are in turn reduced, until the entire rod is brought to a uniform thickness. This method of making iron is still practised in some places, particularly in the preparation of a material for wire and tin-plate, and more especially in the using up of scrap iron.

For a considerable time the only iron that was manufactured in the neighbourhood of Sheffield for local consumption, was from the refuse iron or scraps from the cutlers and other artificers, and scraps imported from Holland. As the demand for Russian iron increased, so did the price, which induced the forgemasters to commence the making of malleable iron from cast or pig metal, by the process before mentioned. The first attempt was with charcoal, with which they succeeded in making a tolerably good article; but the consumption of charcoal was so great, as to compel them to the use of pit coal: the iron, however, made by this mode was of a very inferior quality, and used only for the meaner purposes, being termed coke-iron.

Puddling.

About the year 1780, the consumption of foreign iron having considerably increased throughout the nation, the price was fast approaching to double what it had been during the twenty years preceding. The use of coke having become general, manufactories on that principle increased rapidly throughout the kingdom, competition and the acknowledged deficiency in quality operating as a stimulus to ingenuity and experiment.

According to the best testimony, the first person who introduced or rather attempted a better process was an ironmaster in the county of Gloucester, of the name of Cort; but, like too many other inventors, although he secured his practice by a patent, he was unsuccessful, and ruin overtook him before he could turn to his own advantage that scheme which was presently matured, and became so profitable in the hands of others. The first individual who succeeded, and derived from it a princely fortune, was a resident of South Wales, who had the judgment to perceive and the spirit to patronise the ingenuity of a person who, acting as his engineer, carried toward perfection the art of *puddling*. The process was quickly introduced into every part of the country where the iron trade was carried on: besides, as the invention, by superseding foreign iron, made some noise, and at the same time promised well, many individuals became impressed with the idea, not merely that iron was the most valuable of metals, but that its preparation was the direct way to wealth. This infatuation was too powerful to be withstood; the business was rushed into with capitals of from 10,000*l.* to 100,000*l.*—iron-works multiplied rapidly, the quantity produced exceeded the consumption, competition reduced the price below the expense of manufacturing, and not a few adventurers had to tell a tale of disappointment and ruin.

When this process was first introduced, the only practice was to put the pig metal into the puddling furnace, and there make it into malleable iron; but the experience of ten years showed that a previous operation was essential to perfecting the conversion. This is now termed preparing the metal, and is conducted as follows:—The fire-place is similar to a finery in dimensions and shape, and coke is used as the fuel: half a ton or more of metal pigs are broken up and laid on the fire, and covered with coke; here the whole is melted down, and suffered to remain in the furnace about half an hour after fusion has taken place. It is then suffered to run out at a hole two inches square into a metal trough, by which it is formed into a plate half a yard square, and two inches thick. This when cooled is broken with a sledge hammer into pieces of about one hundred pounds weight each, and thus become ready for the puddling furnace.

The principal chemical change which the metal undergoes during this preparatory process, consists in its being deprived of its carbon; and the advantage gained over the puddling of pig is, in having obtained a greater degree of heat at the commencement of the conversion. The appearance of the metal is very materially changed: in the state of pig, it is soft, open-grained, and of a dark grey; but in plate, it is as hard as steel, close-grained, and nearly as white as silver; it is much more difficult to melt than pig metal, and is not in the least malleable at any heat.

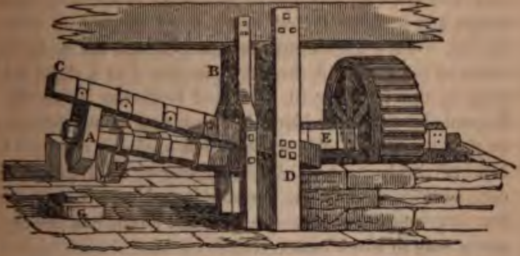
A puddling furnace differs scarcely at all from a common reverberating furnace: the coke fire is placed towards the extremity of the hearth, and is only excited by the draught of the chimney which is placed at the opposite end, furnished with a damper for the purpose of regulating the heat. The iron is laid upon a metal bottom, or, as is more commonly the case, a floor of vitrified sand, of a concave form. The fire and metal are separated by a low wall running across the furnace, but leaving a sufficient space for the fire to pass over the iron: the door is on the side, having in it a hole five or six inches square, through which the workman introduces his tools to stir about and work the iron. The quantity of plate metal put into the furnace at once varies, according to circumstances, from two to three and a half hundred weight; it is piled loosely in the middle of the furnace, and is called *a heat*. In about half an hour after the door has been closed, and the full force of the fire thrown on, the mass begins to melt; when in this semi-fluid state, the puddler introduces an iron rod, turning and stirring the mass about, and occasionally throwing small scoopfulls of water upon it. At this period the metal appears to be in a state of fermentation, being covered with bubbles, which as they burst give out little jets of white or blue flame. When this evolution has gone on for about twenty minutes, the pasty consistency gives way, and the metal disintegrates in a singular manner, falling like river sand, and exhibiting not the least tendency to cohesion. The metal now gives out a dense lurid vapour, upon which appearance the full force of the draught is thrown upon the fire, and the workman stirs about the clod of metal with his tools; and before it becomes a stiff conglomerated mass, he dexterously separates the charge into several lumps of the size of three or four bricks: these lumps, when they have assumed that obstinate clotty consistency which the workmen seek, and which the Shropshire puddlers call *coming into nature*, are drawn from the furnace, and *dolleyed*, or beaten into cakes with hammers, or passed through rollers, according to the purpose for which they are required. These are again heated to a welding heat, and placed under a ponderous hammer moved by water power, and called a stamper, by means of which the iron is perfected. In 1829 a patent was granted for medicating the metal, by using, either in the smelting, refining, or puddling furnaces, about twelve or fifteen pounds of a mixture of salt and potash in the preparation of the iron. Experience seems not, however, to have led to any consideration of this salted iron.

The Forge.

The earliest and most simple contrivance for reducing masses of iron into bloom as well as into bars, when the aid of machinery was brought in, was the working of a forge hammer by means of a water wheel. The common arrangements for this purpose, as they exist in some of our older establishments for the conversion and working of iron, are as rude as they are effective. The annexed cut will assist the reader, who may never have visited the interior of one of these forges, to conceive distinctly the construction and mode of using one of these powerful agents in the hammering of iron on a large scale.

The hammer is represented at A, *fig.* 17.; the shaft or helve is nine feet in length, and thirty or forty inches in circumference, made of ash, and clamped at intervals with stout iron hoops. The head through which it passes in the manner of a common hammer shaft, is of cast iron, and weighs seven or eight cwts. At the opposite extremity this helve passes through, and is firmly fastened with wedges into, a massy collar of cast iron, called the hurst, the two projections or pivots of which form an axis for the hammer, and work horizontally in and between the limbs of the support B.

Fig. 17.



C is a strong but elastic rabbet or spring of timber; it is somewhat lighter and longer than the helve, but like it made of tough ash and bound with iron hoops: it is bolted firmly to the post or puppet D, and likewise to the frame B through which it passes: its use is, by acting as a spring, to send the hammer down towards the anvil with a degree of velocity greater than that with which it would fall by its own weight merely.

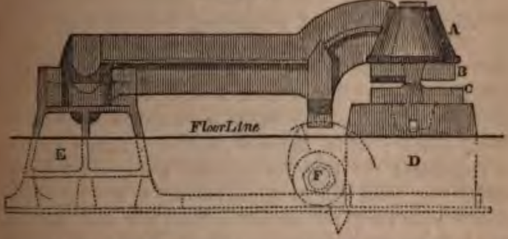
On the near extremity of the water-wheel shaft E, which extends in a direction parallel with the helve, and reaching nearly to its head, is fixed a ponderous circular frame of cast iron, F, about four feet in diameter, technically called an arm-case: holes are cast in this case for the insertion of four knobs or blocks of wood, and these are shod with iron on their acting surfaces. To give motion to the hammer, the water is thrown upon the wheel, the shaft revolves, and the arms or knobs just described as projecting from the periphery of the block in which they are inserted, catch the helve under the belly and lift it against the rabbet; and, constantly proceeding in their revolution, the hammer rises and falls upon the anvil G with a rapidity proportioned to the velocity of the water wheel and the circumference of the lever block on its shaft. The pitch or fall of the hammer between the rabbet and the anvil varies at different forges: it may be stated to be from sixteen to twenty inches. In some forges the water-wheel shaft, instead of being parallel with the helve, is placed at a right angle with it, the hammer in this case receiving its elevating impetus by the lever block knobs acting upon the tenor, or that portion of the shaft which projects through the head of the hammer. An arrangement so obviously incommodious as that last described, and which compelled the forgeman to work only across the anvil, has generally given way to some better plan.

The proprietors of the more recent establishments, and especially where steam is the moving power, have adopted various improvements: the cumbersome wooden framework of the old forges, including the timber, spring-pole, and hammer beam, has been generally discarded, and along with cast iron supports of all kinds, a *metal-helve* has been introduced: this is a ponderous cast iron shaft, through the head of which is inserted the actual hammer, which, by this contrivance, admits of being removed when worn down, and of being replaced by a new one without affecting the helve itself. These hammers, instead of being lifted by an application in front or at the side, are elevated by the operation of what the workmen call a *cam*, revolving under the belly of the helve, as represented in *fig.* 18. This contrivance consists of two or three steel-faced levers, each half-crescent shaped and turning upon an axis, so that as they act in succession upon a projection under the throat of the helve, the latter is made to rise and fall as required, making about 150 strokes in a minute.

These hammers, the faces of which are generally very large, having three degrees of projection, mostly work upon an anvil, the surface of which is likewise divided into three parts; the first is ten or twelve inches wide, and upon this the ball or loop of metal is laid to be shingled; when sufficiently brought together, it is rolled to the narrow or cutting face, and there drawn out in length; after which it is finished on the middle or straight face.

The annexed sketch represents the large metal helve, which along with two smaller ones has been some years

Fig. 18.



in work at the Milton iron-works, in Yorkshire. It weighs about six tons, and measures in length, from the centre of the pivots or trunnions on which it works to the middle of the head A, which is circular, nine feet five inches. The hammer B, which is inserted, and the face of which is divided, as already mentioned, into three parts, for the better performance of its work, weighs eight cwt.; and the anvil C, which in like manner is fitted into a cast metal block, D, is about the same weight; the anvil block itself weighing upwards of four tons. The greater part of this block, and of the frame E in which the helve works, as well as the cam shaft with its lifters F, are below the floor-line as indicated in the engraving by the dotted lines.

Several new mechanical contrivances, particularly the steam-hammer of Mr. Nasmyth, have been introduced into the manufacture of wrought iron with great advantage; but as these are, for the most part, of the same general character as those already described, it is not

thought necessary to take any further notice of the
The following is the chemical composition of the sever
varieties of iron.

	Carbon.	Phosphorus.	Silicon.	Manganese.	Sulphur.
Cold blast cast-iron	4·770	1·230	·710	traces	traces
Hot blast cast-iron	3·430	·370	1·750	1·20	·120
Best Swedish iron -	·293	·077	traces	traces	none
English bar iron -	·285	·180	·230	"	traces
Best scrap iron - -	·245	·160	·210	"	none

Wrought iron, if of good quality, is silvery and fibrous, breaking toughly, and exhibiting the appearance of a bundle of wires. A small quantity of carbon, phosphorus, or silicon increases the brilliancy of its lustre; a dead colour indicates a weak iron, even though it is perfectly white; coarse fibres indicate a strong but inferior article; when, however, it is of a bluish colour it is considered the best for railroad iron. It has been stated that good bar or wrought iron is always fibrous, that it loses its fibres neither by heat nor cold, and that it will bear cold hammering to any extent. It is much doubted if this is correct, since there are experiments which appear to show that the most fibrous, and consequently tough iron, will assume a crystalline structure by long exposure to a vibratory motion; and the action of cold swaging in particular is likely to produce this effect.

Wrought iron, combined with cast-iron in the pig, has been introduced with good effect by Mr. Morries Stirling.

CHAPTER VI.

ANVILS.—ANCHORS.

VARIOUS KINDS OF ANVILS. — IMPROVED ANVIL. — METHOD OF HEATING, FORGING, AND HARDENING. — STOCKS. — ANCHORS. —DIFFERENT SIZES AND QUALITIES. — HAWKE'S PATENT. — CORT.—STUARD'S SINGLE ARMED.—HEMMAN'S MOORING BLOCK. —MUSHROOM ANCHORS.

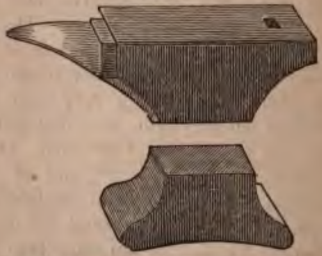
Anvils.

ANVILS are made of scrap iron, of common iron, and even of cast iron; and their relative value and prices are in the order of this enumeration. The latter sort are chiefly used in the forges where iron is made, and for those other purposes in which the metal to be hammered upon them is either not very hard, or not required to be beat out very thin, so as materially to affect the surface or test the solidity of the anvil. In the formation of various articles of steel, and of table-knife blades especially, none but anvils of the first rate manufacture are sufficiently firm to endure the hard and incessant beating to which they are subjected. For in the forging of the blades just named, there is a final hammer process called *smithing,* upon which much of the ultimate goodness of the article depends; and as this process takes place when the blade is comparatively cool and hard, the rebound of the heavy hammer with every stroke is so considerable, that the anvil must be perfect indeed to sustain it. Anvils even of the second description, when used for such purposes as that last mentioned, are not unfrequently seen to crack across their entire substance; though for general purposes and for exportation, they are in very large demand.

The blocks out of which iron anvils are formed are prepared at the power forges, and consist of what are known to the trade by the appellation of *butts.* These butts are of various sizes, being composed of three or four or more blooms, solidly welded together into a cubical mass: in this state they are transferred to the anvil-maker, who brings them into the shape required by immense labour, welding on large projecting pieces, and cutting off superfluous metal with chisels, according to the design he has in view. Some anvil-smiths, instead of thus uniting the beak and the quarter as well as the feet, by welding pieces to the block, forge the upper part of the body, including the beak and the quarter, out of one piece of iron, and the lower portion, with its projections, out of another piece, as represented below.

These parts, represented in *fig.* 19., are then welded together by the horizontal plane, in consequence of which mode, by avoiding all vertical junctures, the anvils are said to be less liable to fracture, as well as being by this course much simplified in the manufacture.

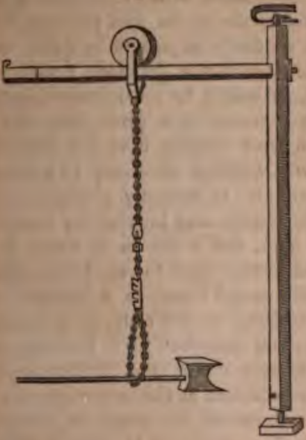
Fig. 19.



As it would be impossible either to manage in the fire a red hot anvil, weighing four or five cwt. (and some weigh much more), or to transfer it to the seat upon which it has to be formed merely by the aid of tongs, the workmen manage it by means of a long and stout iron rod, fixed in a hole made for that purpose in the anvil lump. This rod is suspended towards its farther end by a chain to a crane, the arm of which traversing between the hearth and the anvil-seat, enables the men to move the heated mass with comparative facility. This

ich is suspended from the axle of a collar,
oving on the superior surface of the horizontal
ains towards the lower end a click iron, upon
ing is hung, and which, by being fartened

Fig. 20.



lower, elevates or depresses the loop on the
he height required. For some purposes, and
at nicety is an object, besides this click and
is also a screw regulator, which being turned
of a spanner, admits of the adjustment of
h of chain with the greatest degree of re-
curacy (*fig.* 20.). The seat upon which it
red is a sort of cast-iron bed, raised about
n the floor of the workshop, and having at
isings in the edges to prevent the anvil from
en off during the application of lateral strokes.
excited by the double bellows, made to rise
means of a cross-staff or lever, the motion of
ommunicated by a man who turns a fly-wheel,
ower can be had, by an application to their

under boards of that ingenious but simple contrivance the eccentric wheel.

When the iron body of the anvil is perfected in form, a plate of good steel, about an inch in thickness, is welded upon the face, and assimilated at the edges, till it becomes perfectly united with the inferior mass.

In hardening anvils (as well as large hammers) the mass is not suddenly immersed in water, as is the method with articles of steel generally ; such a course with so large a body would be unsuccessful, as the ebullition thereby caused would be so great, that the steel would be prevented from coming into that immediate contact with the water which is necessary to produce hardness. Instead, therefore, of instantly plunging the anvil, it is suspended by chains, and lowered by means of a windlass into a tank, and a stream of water from above is then suffered to run upon the steel face, until the latter be sufficiently cooled ; and, as it becomes tempered by the heat remaining in the body, it is dropped into the water below, and quenched till it becomes quite cold.

The anvils upon which steel articles are to be forged are generally fashioned at the bottom merely in the form of cubes for insertion, by means of wedges, either in stone or wooden stocks : a blacksmith's anvil, on the contrary, as well as others, is formed with a projecting base, and buttresses at the corners, in order that it may stand firmly upon the surface of a stock which is always of wood. Two other descriptions of *stocks*, not in common use, were mentioned in the newspapers a few years ago ; the first a female, who suffered a blacksmith's anvil to be placed upon her breast, while a horseshoe was actually turned upon it by the hammer ! the other was formed of the butt end of an oak tree, and was fixed in a smith's shop, at a village called Gargrave ; from this butt healthy stems and leaves continued to shoot for some time, though both the principal roots and the bark had been removed.

Anchors.

Anchorsmiths have long been acquainted with the application of the forge hammer moved by machinery, as auxiliary to the common sledge hammer, in the formation of those ponderous articles of their trade upon which the security of such a large amount of life and property while afloat on the sea, so materially depends. The use of anchors is almost as ancient as the art of navigation itself. The earliest known contrivances for the fastening of vessels could, indeed, scarcely with propriety be called anchors, as, according to the testimony of various authors, they consisted merely of sand bags, or metal weights, appended to ropes, and dragging on the bottom, so as imperfectly to detain the ships, as the drag might happen simply to lie upon or partially sunk into the ground. The term anchor, indeed, from the Greek αγκυλος, *crooked*, was not strictly applied by navigators till the implement, of so much importance to them, began to be made of metal in the form of a hook; an improvement, or rather invention, which Pliny ascribes to the Tuscans, and which has likewise been, by other writers, attributed to various nations and individuals. The antiquity of the double-armed anchor, somewhat resembling that commonly in use, as well as of the other, is so remote that its origin is equally involved in obscurity and fable. As the progress of a spirit of adventure or commercial speculation increased the vessels in bulk, and urged their departure into remote regions, the anchors which they carried with them became objects of increasing anxiety. Hence modern shipbuilders and anchorsmiths have devised various alterations and improvements in the fashion and materials of this essential appendage to every vessel of considerable size. In form, however, there have been, strictly speaking, but few and inconsiderable deviations from the figure generally so well known, even to those persons who never saw a ship; until of late years, when not only has great attention been paid to the selection and combination of materials in the formation of anchors of the usual shape, but more complex methods of fabrication have been successively introduced.

The constituent parts of the common anchor are the shank, the stock, the ring, and the two curved arms, with their flukes. In the common anchors of most European and other mercantile nations all these parts are of solid iron, except the stock, which is generally composed of two cheeks of wood, fastened together by means of hoops, and treenails, sometimes of metal, and is fixed through or across the upper part of the shank, at right angles with the arms, in order that, when it reaches the bottom, by lying horizontally, it may tend to give a groundward direction to the flukes; so that when one of the latter is fairly imbedded the stock lies flat upon the ground. The Spaniards, and some other less civilised nations, have used anchors made of copper.

Various rules and proportions have been given by different writers, as proper to be observed in the formation of anchors. Aubin, in his marine dictionary, says that the length of an anchor should be four tenths of the greatest breadth of the ship; so that, supposing a vessel to be thirty feet wide, the shank of the anchor would be twelve feet long. Manwaring, another authority, proposes that the shank shall be three times the length of the flukes, and half the length of the beam. It is admitted, according to a principle of hydrostatics, that within certain limits a heavy vessel is detained by a smaller anchor than a light one of similar size; because, although the bulk offered to the power of the tide be the same in both cases, the resistance will be inversely as the buoyancy of the two bodies in the water. M. Bouger, a French author, in his "Traité de Navire," has laid down the following proportions: — the two arms should form the arch of a circle, the centre of which is three eighths of the shank from the vertex or point where they are fixed, and each arm is equal to the same length or radius; so that the two arms taken together describe an arch of 120 degrees: the flukes are half the length of the arms, and their breadth two fifths of the said length. The thickness or circumference at the throat or vertex of the shank is generally a fifth of its length, and the small end two thirds of the throat: the small end of the arms of the flukes may be three fourths of the circumference of the shank at the throat. Different anchor-makers, however, have their respective rules of proportion; and when the iron is of an inferior quality, and especially when cast iron is used, the dimensions will be required considerably to exceed those given. For an anchor weighing four tons, which is about the largest size, the following formula may be given: —

Length of shank, nineteen feet six inches; length of arms, six feet six inches; breadth of the palms, three feet two inches; size of the trend, nine inches and three quarters; size of the small round, eight inches and a quarter; outer diameter of the ring, thirty-eight inches; thickness of the ring, four inches. Some of the cast-iron anchors carried by the ships of war weigh nearly five tons.

Every large ship has divers anchors; the three principal ones, however, are the sheet anchor, or that which was called by the ancients *anchora sacra*, and the best and second bower anchors, so designated from their respective situations on the bows of the vessel.

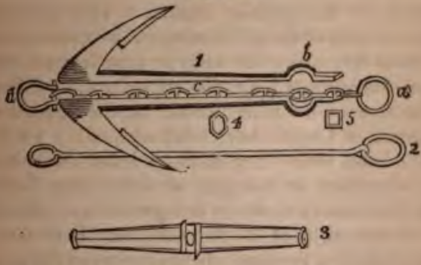
Whatever be the construction of anchors, two important desiderata are, tenacity and stiffness in the materials: a deficiency in the former of these qualities leaves the anchor extremely liable to break when subjected to those heavy strains which they are so frequently required to withstand, when large vessels are exposed to the influence of wind or tide, and sometimes to the united violence of both. Too great a degree of softness, on the other hand, creates a risk scarcely less to be apprehended, from the straightening and consequent detachment of the arm of the anchor from its hold upon the bottom. To unite these two properties, tenacity and stiffness, with the least available weight of metal, forms the principal feature of modern improvements.

In order to secure these objects, various plans have been proposed, and patents obtained by ingenious individuals. Among other methods, it has been recommended to make the shank hollow, and insert therein a wooden core, and likewise to make the anchor of several pieces, as well for lightness as for convenience of manufacture and stowage. A patent for an ingenious article of this description was, in 1823, granted to a ship-builder of Stepney of the name of Hawke. An extract from the specification of this artist will serve to illustrate the nature of the innovations alluded to. The anchors at present in use are made by forming the shank and the arms on flukes separately; they are then, when of a welding heat, united together by hammering, and the cable is fastened to a ring or shackle, passed sideways through the shank at the upper extremity. The stocks, if of wood, are let or scored over each side, and bolted and hooped over the shank of the anchor; if of iron, the eye for their reception is punched through the shank of the anchor.

The improvements asserted in Mr. Hawke's patent consist in forming a part of the shank and all the fluke of one piece in the length of the anchor, and bending them to the form required; and should the bars of iron not be manufactured long enough, they are to be welded, and the welds separated in the number of bars that are sufficient to make the size required. Parts of anchors thus made will not be liable to bad welding, or to be burnt by the intense heat required to make the weld; the iron likewise by this process will experience a severe trial in bending. The shank is to possess flanges along its sides, or a channel down the inner surface of the two sides, to admit the chain or bolt to pass through; and an eye is to be opened on each side or piece of the shank, to allow the wood stock to pass through, which stock is to be made round or otherwise in two halves, one to pass each way with iron shoulders on each piece, so that when hooped it cannot get out of the eye of the anchor. Three or four fluked anchors are to be constructed in parts in a similar manner. The annexed figures will enable a person more perfectly to understand these improvements.

The anchor as shown in *fig.* 21. is formed with a groove down the middle for the cable to pass through, and which, if of chain, is attached to a ring *a*; if of hemp, it may be knotted or otherwise: *b* an eye or opening to receive the stock; *c* is a piece of chain laid in the groove; the ring or shackle *d* at the crown end is for the buoy rope, and by it the chain is held fast. At 2 is shown a stout iron rod, which may be used for the same purpose as the chain. At 3 is represented the stock as united by the hoops at each end; and 4 and 5 are hoops such as are driven over the shank to keep the two cheeks together.

Fig. 21.



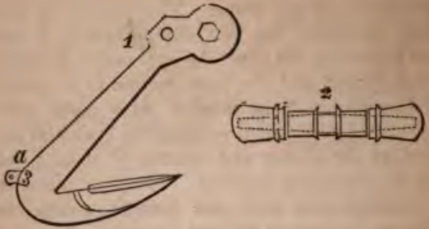
A patent for a compound anchor, not differing materially from Mr. Hawke's, was granted in 1828 to Lieutenant Rodger of the royal navy. It consisted of a hollow shank, which was to receive a core of wood, and which, with the stock, was composed of several pieces bolted together; and thus, according to the patentee, affording greater facilities for welding the fluked arms to the sides or component pieces, these being much more portable than the entire anchor. One standard objection alleged against these ingenious contrivances in general is, that while the increased workmanship adds to their expense, they do not seem calculated to afford additional security.

At the Great Exhibition in 1851 were exhibited several kinds of anchors; those, however, of Lieutenant Rodger were considered greatly superior to any others, as insuring a better distribution of the metal in the direction of the greatest strains. The palm of the anchor, instead of being flat, presents two inclined planes, calculated for cutting the sand or mud instead of resisting perpendicularly; and the consequence is, that these new anchors hold much better in the ground. The committee of Lloyd's have resolved to allow for the anchors of the ships they insure a sixth less weight, if made according to the plan of Lieutenant Rodger.—Than this there can scarcely be a greater recommendation.

The best anchors of the solid sort have long been acknowledged to be those which are forged from bundled or scrap iron. For the introduction of an improved method in preparing the material, the manufacture is indebted to Mr. Henry Cort, the individual who led the way to the present all-important practice of puddling in the conversion of cast into malleable iron. His method was in the making of shanks, arms, rings, and palms of anchors, as well as mooring and bridle chain links, to cause bar iron of sufficient length to be closely fagotted or bundled together, by laying, in the first place, at the bottom a broad flat bar of the width and length required; upon this were laid either other flat bars, or other descriptions of iron, such as old hooping, &c. The materials being arranged, the whole mass was bound together by collars driven on tight, or by strips of iron wrapped firmly about the bundle. Several of these faggots being thus prepared, were placed in a common air furnace, or *balling furnace*, as it is called, and therein brought to a welding heat. When the heating was perfected the faggots were withdrawn, either singly, or two or more to be welded together, as the case might require, under a forge hammer of 8 cwt. or 9 cwt. When the faggots were too heavy to admit of this operation being conveniently performed by hand, a crane was used, but generally two men, with their assistants, would manage a mass of 3 cwt. by hand; lifting from the furnace, and working it on the anvil better than with the assistance of the crane. The forging of anchors, however, is, under the best circumstances, a most laborious business; but since the application of machinery to the hammer, and the introduction of a contrivance called Hercules and the monkey, or a crane similar to that described under anvil making, the muscular exertion required in the lifting and beating of these ponderous articles is materially lessened. Mr. Cort remarks, that by a welding heat from the furnace, palms may be brought on the arms of anchors under the forge hammer with greater certainty and better effect, than by the methods in practice before his invention. He states also, that he has found that the fire in a balling furnace is better suited, from its regularity and penetrating quality, to give the iron a perfect welding heat throughout its whole mass, without burning any part, than any fire blown by a blast; insomuch that if bar, or other massy iron, is bound into a faggot of five or six inches diameter by an old cask hoop the sixteenth of an inch in thickness, the one will acquire a complete welding heat, and the other not be burnt or wasted; whereas bar iron, faggotted and made into anchors or other large articles, in the method usually practised by anchor-smiths, is not completely welded to the centre, but rather covered only with an incrustation of welded iron, and, consequently, more liable to decay, and many accidents, than will be the case with the iron which is perfectly welded throughout its entire substance.

An anchor, advocated several years ago by a person of the name of Stuard, is represented in *fig.* 22. Having but one arm, it does not require welding, but may be bent out of a single piece of iron; it may also be made very strong, and yet not weigh so much as a common anchor with double flukes, especially as it is made with a short shank; *a* is a small shackle, on the bend of the shank, to which the buoy rope is to be affixed. 2. is the stock, which is composed of two pieces of wrought

Fig. 22.

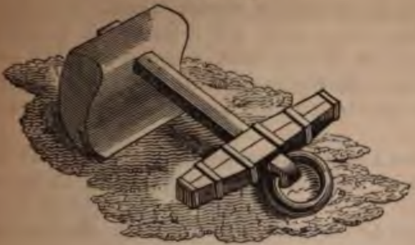


iron, forming a mandril when placed together through the eye of the anchor: upon these are cast pestles of pig-metal, each hollowed to receive the core of the other, so that when driven up together they form a compact stock of metal.

A substitute for the common anchor for vessels riding in the roadsteads of our coasts, was proposed in the mooring block introduced some years since by Mr. Hemman, of Chatham. This block is, in fact, a ponderous claw of cast-iron, weighing about 150 cwt., which is about 60 cwt. heavier than the anchor of a first rate ship. According to a communication made by the inventor to the Society of Arts in 1811, the saving to a ship of the line from the use of these blocks was 874*l.* out of 2472*l.*, the estimated expense of a pair of moorings with anchors. *Fig.* 23. represents a perspective view of the mooring block as it appears when lying upon the ground.

In 1821, R. F. Hawkins, a Kentish mariner, obtained a patent for an anchor, the arms and flukes of which turned round in eyeholes at the termination of the shank, until they formed therewith an angle of about sixty degrees, in which position they were detained by a thick piece of iron, called by the inventor a "toggle." When this anchor is let go, one of the ends of the toggle comes

Fig. 23.



in contact with the ground, and puts both flukes in a position to enter; and when the strain comes on the cable, the other end of the toggle, by coming in contact with the throat, sets the anchor in its holding position, not with one fluke only, as in the common anchor, but with both.

In the same year with the foregoing, another patent for "an improvement on, or substitute for anchors" was granted to Mr. Christopherson, of London; the principal novelty in this article consisting in dividing the substance of the shank into two, three, or four branches, and fastening them, by riveting or otherwise, to the holding part, or what, in ordinary acceptation, might be called the flukes of the anchor. These, however, instead of being at the extremity of arms, as usual, are component parts of an hemispherical metal block, and constituting, in fact, a sort of mushroom anchor.

Mr. H. Gosling, a naval officer, proposed an anchor with five arms or flukes, and altogether without the common wooden stock or crosspiece; so that the flukes radiating from a centre were sure to take the ground, fall in what manner soever they might. — Its advantages were thus stated: —

1. That it is particularly calculated for a working anchor with a chain cable, as a vessel can always ride at single anchor, without danger of fouling it.

2. That it stows clear of a large ship's lower deck

ports; not impeding a ship's way, as an anchor with a stock does, particularly in smaller vessels.

3. That a chain cable will never foul it beyond the certainty of its clearing itself as soon as the strain ceases on the cable; thereby not capsizing or turning the anchor over, but leaving it in the same position as when first let go.

4. That a hemp cable must also always clear itself in the same manner, and leave the anchor in the same position.

5. That by dispensing with the stock, there is not so much danger of the shank snapping.

6. That it may be got on board for easing the ship, or for stowage, with much greater facility than the common anchor, and does not require to be of greater weight than those at present in use; for large ships, the shank 31 cwt., each fluke 10 cwt.; total 81 cwt.

CHAP. VII.

CHAIN BRIDGES.

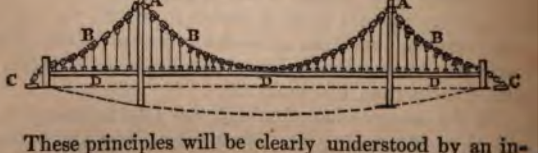
ANCIENT SUSPENSION BRIDGES.—PRINCIPLES AND DEGREE OF TENACITY.—EARLIEST CHAIN BRIDGES.—THE MENAI SUSPENSION BRIDGE.—HAMMERSMITH BRIDGE.—SUSPENSION RAILWAYS.

THE curiosity of the British nation, which had been so much excited by the use of cast iron as a substitute for stone in the construction of bridges had scarcely begun to subside, when it was again called into still more powerful action by the application of wrought iron to a similar purpose, but on a principle implying the exercise of a superior ingenuity, and the nicest application of a knowledge of the mechanical powers, and properties of the material employed.

Portable rustic bridges composed of ropes, so arranged as to be hastily thrown over a river to facilitate the transit of the native hackeries have long been known in India: these, though differing so essentially in the simplicity of their formation, and the fragility of their materials, deserve, nevertheless, from their similarity of principle, to be considered as the prototypes of our more elaborate and massy suspension bridges of iron. It has indeed lately been asserted on anonymous authority, that the largest *iron* bridge in the world is in China, near Kingtung, where it forms a perfect road from the top of one immense mountain to another: moreover, that it is formed of twenty chains, bound together by cross chains; and is more than 150 years old.

In the construction of bridges, on what is termed the principle of *tenacity*, the objects are to form and adjust their several parts with a particular view to that important quality of the metal, which disposes it, on being stretched, not merely to resist and keep its hold, but apparently to draw or pull in a direction opposite to that in which the force that acts upon it is applied. In the construction of cast iron bridges, the metal is generally employed like any other merely hard or bulky substance that is capable of having its pieces connected together; and the several pieces of which are arranged to rest and press against each other, as if they possessed no other property than their solidity, extension, and weight. In the Southwark bridge, for instance, we see the plates of iron that compose the arch, cast on a similar plan, and arranged in a like order, and depending nearly in the same way upon one another, as the blocks of stone in the arches of Waterloo bridge, and requiring, in consequence of that arrangement, a corresponding bulk and strength in the piers and abutments, not only to bear the perpendicular pressure or gravity of the materials, but to afford an adequate resistance to what is termed the lateral pressure, or bearing of the extremities of the arch upon the bases on which they rest. In the construction however of suspension bridges, the iron is made use of so that its property of *tension* should be most advantageously employed, and the pieces of which the structure is composed are so adjusted with a view to the mutual dependence of the parts, and the independence of the whole, as to diminish the necessity of bulk, without injury to the strength of the fabric; and to promote a proportional lightness in its appearance and effect, at the same time that it almost annihilates the lateral pressure.

Fig. 24.



These principles will be clearly understood by an inspection of the slight sketch, *fig.* 24., annexed, which, although it does not represent the actual appearance of any real erection, will show the disposition of the materials in their simplest combination.

A A are two stakes placed at proper distances from the banks of the stream on either side. Passing through these stakes towards the top, the chain B B B is extended somewhat slackly, or so as to fall in a versed sine of the required curve, and passing through low posts on each bank to the mooring blocks at C C, is there fastened. D D D shows a line of planks reaching over the river and passing between the stakes: this foot-way is linked at intervals, and thus suspended by perpendicular rods or wires on both sides; one side only being shown in the cut. The upper line of dots is intended to show the surface of the water, and the lower line the bed of the river. From this illustration it will be plain that the simple gravity or downward pressure of a weight on any given part of the bridge road, will be reduced in a certain ratio by distribution through the entire length of the chain, which draws or strains from both its extremities, and, consequently, must slightly traverse on a pulley in the perforation of the upright stakes. Hence, while the materials retain their cohesion, and the fastenings remain firm, any pressure in the centre sufficient to alter perceptibly the form of the bridge must first overcome the curvilinear direction of the chains, causing thereby a dip but not necessarily a disruption.

Of course, the strength and weight of the materials in a work of this kind, as in all others, must be adapted to the degree of pressure likely to be encountered, as well as for resistance under the collateral circumstances which may be expected to test its stability. According to experiments made in Russia in 1824 to determine the tenacity of iron, and transmitted to this country by Mr. Saule, *Ann. des Mines*, x. 311., it was found that the best iron supported twenty-six tons per square inch, without being torn asunder; whereas the worst iron gave way under a tension of fourteen tons to the square inch. By forging four bars of iron of a medium quality together, an iron was obtained which did not begin to lengthen until sixteen tons had been applied, and supported a weight of twenty-four tons without breaking. Hence it was decided by the Petersburgh committee, appointed for the purpose, that the thickness of chains in a suspension bridge should be calculated so that the maximum weight to be borne should not be more than eight tons per square inch of sectional surface; and that, before being used, they should be subjected to a tension of sixteen tons per square inch, and bear it without sensible elongation.

Experiments made to discover the resistance to tension possessed by malleable iron, have, as might be expected, produced various results. In the greater number of cases 80,000 pounds to the square inch has been given; and in none, where the material was sound, under 50,000 pounds; so that about 60,000 pounds may be taken as the average: and according to Tredgold, no material, as Emerson had previously concluded, should be put to more than a third or even a fourth of the weight that would break it. Generally it is admitted, that, besides the little interruption caused to the flow of the current by means of piers, and the slight interruption caused to the navigation of a river, as well as the saving of time, one half of the iron may be considered sufficient for the construction of a bridge on the suspension principle, that would be necessary for one of the same size on the ordinary plan.

The following tables are from the *Report of the Commissioners appointed to inquire into the application of iron to railway structures.*

From the extent of the experiments made by Professor Eaton Hodgkinson and others who assisted the commissioners, we can do no more than give a selection from the reports. In this selection, we have been guided by peculiar differences in the result, without any reference to manufacturers or localities.

Description of Iron.	Breaking Weight in Lbs.	Breaking Weigh per Square Inch of Section, in Tons.
Low Moor iron, No. 2.	67,667	6·901
Clyde iron, No. 2. -	74,835	7·949
Blaenavon iron - -	79,315	7·466
Calder iron - -	64,083	6·131
Coltness iron - -	78,419	6·82
Brymbo iron - -	63,579	6·440
Bowling iron - -	63,579	6·032
Ystalyfera iron - -	55,067	5·602
Yniscedwyn iron - -	60,443	5·959
Mr. Morries Stirling iron* - - -	87,827	11·502

Crushing Strength of Cast-Irons

Description of Iron.	Mean crushing Weight per Square Inch of Section, in Tons.
Low Moor iron - - - -	27·004
Clyde iron - - - -	42·825
Blaenavon iron - - - -	38·263
Calder iron - - - -	33·075
Coltness iron - - - -	45·091
Brymbo iron - - - -	33·592
Bowling iron - - - -	33·508
Ystalyfera iron - - - -	43·635
Yniscedwyn iron - - - -	34·430

Strength of various Kinds of Pig-Iron.

1. *South Welsh Cold-Blast Pig-Iron.*

	Breaking Weight in Lbs.
Pontypool - - - - -	8,120
Crawshay - - - - -	7,410
Porthcawl - - - - -	6,300
Blaenavon - - - - -	6,730
Ystalyfera - - - - -	6,680
Maesteg - - - - -	6,010
Nantyglo - - - - -	5,770

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* This, as previously stated, was a combination of wrought and cast-n.

2. Scotch Hot-Blast Pig-Iron.

	Breaking Weight, in Lbs.
Clyde	5,170
Govan	5,030
Calder	5,350
Gartsherrie	5,380
Langloan	5,380
Dundyvan	4,480

The following result of an experiment on coupling chains, lately made at Manchester by the London and North-Western Company will be of interest.

Best Staffordshire iron. First experiment; diameter of chain $1\frac{1}{8}$ inch, stretched $3\frac{3}{4}$ inch; broke with 27 tons 10 cwt.

Best Staffordshire iron. Second experiment; diameter of chain $1\frac{1}{8}$ inch, stretched $4\frac{1}{8}$ inch; broke with 25 tons.

Low Moor iron; diameter of chain $1\frac{1}{4}$ inch, stretched 7 inches; broke with 55 tons 16 cwt.

Some important experiments are reported in an American periodical, which were made with a view of testing the strength of the iron manufactured from the Franklinite ore of New Jersey. The following are the reported results.

	Lbs.
Best Swedish bar iron	72,804
Inferior „ „	53,224
Best English bar iron	61,660
Inferior „ „	55,000
Franklinite bar iron	77,000

It appears, from a description of bridges of suspension, communicated some years since by R. Stephenson, esq., civil engineer, to the "Edinburgh Philosophical Journal," that the first chain bridge constructed in this country is believed to have been one over the Tees, forming a communication between the counties of Durham and York. It is supposed, on good authority, to have been erected about 1741, and is described in Hutchinson's "Antiquities of Durham," as "a bridge. suspended on iron chains, stretched from rock to rock, over a chasm near sixty feet deep, for the passage of travellers, particularly miners.

The bridge is seventy feet in length, and little more than two feet broad, with a hand-rail on one side, and planked in such a manner, that the traveller experiences all the tremulous motion of the chain, and sees himself suspended over a roaring gulf, on an agitated and restless gangway, to which few strangers dare trust themselves."

In 1816–17, two or three bridges of iron wire were constructed; the first by Mr. Lees, an extensive woollen manufacturer at Galashiels in Scotland. This experiment, although made with slender wires, and necessarily imperfect in its construction, deserves to be noticed, as affording a practical example of the tenacity of iron so applied. These wire bridges were suspended, not upon the catenarian principle so successfully adopted in the larger works subsequently undertaken, but by means of diagonal braces, radiating from their points of suspension on either side, towards the centre of the road-way. The unfortunate fabric next mentioned was constructed on this defective principle.

Among the earliest practical exhibitions of this novel architecture in the United Kingdom, may be mentioned the uncommonly elegant and light chain bridge which was, in 1817, for the convenience of foot passengers, thrown over the Tweed at Dryburgh, by the earl of Buchan. Its length, between the points of suspension, was 261 feet, being considered the greatest span of any bridge in the kingdom. This useful structure, the theme of such just applause, and which harmonised so finely with the far-famed scenery of Dryburgh abbey, was entirely destroyed by a tremendous gale of wind, at the beginning of the year following its erection.

Such, however, was the utility of Dryburgh bridge, when compared with a troublesome ferry, even during the short experience of six months, that lord Buchan, upon whom had fallen the whole expense of the former bridge (*500l.*), without hesitation directed that it should be restored immediately. This was accordingly done, after a better design, for the additional sum of about

220*l.*, and in less than three months it was again opened to the public. The new bridge was constructed upon the catenarian principle, the road-way being suspended by perpendicular rods of iron.

The disaster attending the first erection at Dryburgh did not deter British ingenuity and perseverance from the commencement, in another part of the kingdom, of another structure on the same principles, but still more magnificent in its design. This was the famous bridge over the straits of Menai, and uniting Wales and Anglesea. It was designed and erected by Mr. Telford, who had already distinguished himself in the same neighbourhood by the construction of the superb aqueduct over the vale of the Dee, called Pont Cyssylttir.

An account of the progress of this stupendous work of art, exhibiting, as it does, the application of malleable iron on the largest scale, must be acceptable no less as a record of the triumph of science, than as a narrative of general interest. It is derived from the account by Dr. Pringle, who resided in the vicinity of the bridge, and attended regularly to the progress of the structure.

The first operations of the workmen took place in May, 1819, and consisted in blasting the rock called Ynys-y-nuch, which was then only accessible at low water, in order to form a solid foundation for the north main pier on the Anglesea side. For this purpose, in a few months afterwards, the intermediate space between the Anglesea shore and the rock was filled up with a temporary causeway of stone-work, wide enough to admit of a rail-road for sledges drawn by horses, and which being considerably elevated above high water mark, afforded the workmen an opportunity of passing and repassing to their various occupations at all times without hinderance. Previous, however, to the shutting up the navigation (as authorised by an act of parliament), for the purpose of carrying the suspension chains over without interruption by vessels passing through the straits, this temporary causeway was taken down, and the channel made considerably deeper and wider than before, by which means coasting vessels of a moderate tonnage were now, for the first time, enabled to pass through this narrow strait with perfect ease and safety. The impetus of the tide in this part of the strait is at the rate of five miles per hour.

The temporary causeway being completed, and the rock rendered level by the aid of masonry, the first stone of this astonishing work was laid privately by Mr. W. A. Provis, the resident engineer, on Tuesday the 10th of August, 1819. In the autumn of the same year the preparations for the foundation of the south main pier on the Caernarvon side were begun.

This pier, from the depth of its foundation (seven feet), exceeds considerably the one on the opposite shore both in masonry and workmanship; a distinction which is very apparent at low water. The four arches on the Anglesea side, which for magnitude and grandeur can hardly be surpassed, were begun early in the spring of 1820, and completed in the autumn of 1824. This work is built of a grey marble, procured upon the sea-shore N. E. of the island of Anglesea, on the property of lord Bulkeley, for which his lordship was paid sixpence per ton by government.

After the completion of the seven large arches, the smaller ones intended for the road-way were constructed, each being fifteen feet to the spring of the arch, and nine feet in width, through which carriages, &c. were to pass. When the arches were turned, the suspension piers were further elevated, tapering gradually in a pyramidical form, to the height of 53 feet from the level of the road by solid masonry, each stone being bound by iron dowels from the top to the bottom of these piers, to prevent their being separated or bulged by the immense pressure of the suspension chain.

The next process was the iron department. On the extreme height of the suspension piers are placed the cast-iron blocks or saddles (with wrought iron rollers and brass bushes) for the purpose of regulating the contraction and expansion of the iron, by moving themselves either way as may be required, according to the temperature of the atmosphere, without causing the least derangement in any part of the work. These rollers are most ingeniously constructed, and form a desideratum in this line of bridge building.

In order to form a permanent seat, grasp, or hold for the iron frames, to which the lower or extreme ends of the suspension chains were to be made fast, three oblique cavities or openings, of a circular form, and about six feet diameter, were made by blasting in the natural body of the rock on the Anglesea side, leaving a considerable width of rock for the suspension chains. These excavations were carried down like an inclined plane to the depth of twenty yards.

This being accomplished, a connecting avenue or chamber was formed horizontally at the bottom of the cavities, sufficiently capacious for the workmen to fix the iron frames, composed principally of flat cast-iron plates, which were afterwards ingrafted as it were into the natural rock, so as to bid defiance to any stress that might bear upon them, and to be immovable unless the solid rock itself could give way. A similar mode of proceeding was adopted on the Caernarvonshire side.

The suspension chains, which are made exclusively of wrought-iron, being firmly secured and made fast to the iron frames just mentioned, the chain bars, each ten feet in length, were then laid down by placing five together—equivalent to one breadth of the chain, and carried on by consecutive lengths, joined by flat iron plates and bolts, to the apex of the suspension piers, supported underneath all the way up by a temporary frame-work of strong timber, the upper end of the chains resting on the cast-iron saddles which had been placed there to receive them. A similar course was pursued with the ascending portion of the chain on the Caernarvonshire side; only that from a difference in the ground this required to be lengthened by additional chain bars from the apex of the pier perpendicularly nearly to high water mark.

On the 26th of April, 1825, the first chain of the curved part of this stupendous work was thrown over the straits of Menai; the day was highly propitious, and the joy of the interested spectators, as might be expected, very great. A larger concourse of persons than it is believed ever assembled in the situation before, crowded the Anglesea and Caernarvonshire shores, to witness a scene such as their ancestors never conceived. Mr. Telford attended to see this part of his grand scheme carried into effect. Soon after noon, it being half-flood tide, the raft, which was 450 feet long and 6 feet wide, stationed on the Caernarvon side, and which supported the part of the chain intended to be drawn over, began to move slowly from its moorings, towed by four boats to the centre of the river between the two grand piers: when the raft was brought to its ultimate situation (which was in about twenty minutes), it was made fast to several buoys anchored in the channel for that purpose. The part of the chain pending from the apex of the suspension pier was then made fast by a bolt to the part of the chain lying on the raft. The next operation was fastening the other extremity of the chain, still lying on the raft, to two large blocks for the purpose of hoisting it up to its intended station—the apex of the suspension pier on the Anglesea side: the tension of the chain at this time was forty tons. When the blocks were made secure to the chain, two capstans and also two preventive capstans commenced working; each capstan being propelled by thirty-two men, two fifers regulating their steps, and enlivening the scene by playing an appropriate tune. The chain rose majestically, and before five o'clock the final bolt was fixed amidst the hearty acclamations of the thousands of spectators who thronged the ground on both sides. Not the least accident, delay, or failure of any kind occurred throughout the day.

On the completion of the chain, three of the workmen had the temerity to pass along its upper surface, which forms a curvature of 590 feet; the versed sine of the arch is 43 feet. On the termination of the day's proceedings, the workmen, 150 in number, were regaled, by order of the right honourable the parliamentary commissioners of the Holyhead road improvements, with a quart of *crw da* each.

The other fifteen chains were carried over in as many days; the entire line of suspension being completed by the insertion of the last bolt on the 6th of July. The chains being all adjusted, and placed equidistant to each other, the vertical rods were fastened to them: the lower ends being firmly bolted to the iron sleepers, on transverse rod bars, each vertical rod and sleeper being placed longitudinally, five feet apart. There are 111 of these sleepers, to each of which are attached transversely four vertical rods, making the whole number of rods between the suspension pier 444.

The next process was the formation of the roadways: these consist of two carriage lines, each twelve feet broad; and a footpath, four feet wide, in the centre between them, inclosed all along by an iron railing to preserve passengers from accident.

On the 30th of January, 1826, this singular structure, which during its progress had excited so much attention, as well from its novelty as its magnitude, was opened to the public by the London and Holyhead mail coach passing over with the bags for Dublin. About 5000 persons who were present were then allowed freely to parade the platform for several hours. On the 1st of February the first three-masted vessel passed under the bridge, with all her spars up: her topmasts were nearly as high as those of a frigate, yet they cleared twelve feet and a half below the centre of the roadway.

In 1828 a magnificent bridge, on the suspension principle, was completed over the Thames at Hammersmith. This handsome as well as useful fabric consists of one curved or versed sine, similar to the Menai bridge. The links were all previously tested to 45 tons each. The total weight of the metal is 472 tons, 2 cwt. 1 qr. 24 lbs.

In this example of the application of malleable iron, 1622 pieces were from the Brierly Hill, and about 3000 pieces from the Gospel Oak works; the remainder, including most of the particular pieces, was executed at the forges of the Glamorganshire firm of Brown, Lenox, and Co., where the iron-work for the Union bridge over the Tweed, the Brighton chain-pier, and other suspension bridges, was manufactured. The bars for the chains of Hungerford Bridge were manufactured by the firm of Sandys, Carne, and Co., Hayle, Cornwall.

It may be added, that the chains of the Hammersmith bridge were formed of wrought-iron bars, made from the best iron, welded together of thin flat bars under a forge hammer, until the entire length and shape were produced without a shut. In the centre part of the end of each link or bar, as is already stated, a bolt hole, of 2¾ inches diameter, was drilled out of the solid, so that the iron has not been subject to any of the defectiveness and uncertainty in the manufacture, so usual in the common mode of forming chains, or punching holes in iron, by which it is very much weakened by compression and distension; and as great accuracy was necessary, that each bar should have its due proportion of strain when put together, they were packed in parcels of three and six links, and bored through, by which means the greatest accuracy was obtained. The principle upon which the links of the catenary chord is formed and united, resembles that displayed in the chain of a common watch, especially if the parallel pieces of the latter be supposed to be considerably elongated and pinned together in threes and sixes.

A chain bridge erected by subscription at Morpeth, in Northumberland, in 1827, fell down three years afterwards, on the following occasion: — There were some mountebanks in the town, and they were performing on a piece of waste-ground on the south side of the river, called the High Stanners: after the performances were over, as the crowd was returning by the chain bridge at the foot of Aldgate, it came down with a tremendous crash, by reason of the great weight of the persons upon it, and precipitated them into the river. Several children's arms and legs were broken, but fortunately no lives were lost.

Several suspension bridges have been most seriously injured by strains, produced by the wind. The chain pier at Brighton was considerably damaged during a violent storm, which occurred on the 15th of October, 1833, many of the suspending rods being broken, and a considerable portion of the roadway in two of the divisions being carried away. The suspension bridge at Montrose had one third of the roadway, or platform of the bridge, carried entirely away, October 11. 1838. On the 7th of January, 1839, by a heavy storm, more than one third of the suspension rods of the Menai bridge were broken, and both the carriage ways rendered impassable; nearly 200 feet of one of them being broken away. During the height of the storm, a wave was observed to traverse the platform in an oblique direction, the height of which was estimated by the bridge keeper at not less than sixteen feet. The motion was observed to be greatest about halfway between the points of suspension and the centre of the bridge. The wave increased in its progress from the tower, until it attained its maximum altitude near the first quarter, and at the same instant the extreme depression was near the third quarter. The wave then gradually diminished to the centre of the bridge, and afterwards increased to the third quarter, where it attained its greatest height, at the same time as the first quarter was most depressed. The platform and the main chains were equally subject to this undulatory motion.

A suspension bridge at Broughton, near Manchester, was broken down in 1831, in consequence of the vibration occasioned by a company of about 60 soldiers marching over it. One of the chains suddenly broke, and the whole of the men were precipitated into the river.

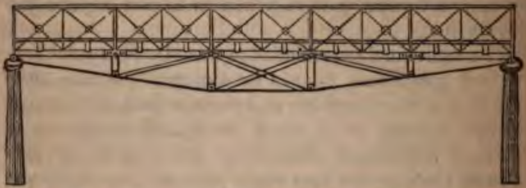
Undulations produced and propagated in the chains and platforms are thus shown to be of the most serious consequence, and the instances given show the necessity of adopting means for preventing, as far as possible, this tendency to vibration. It is important to render the platform as stiff and rigid as possible, and, further, to connect the chains on each side of the bridge so together as to constitute essentially but one chain, as in those of Hungerford Bridge, so that, their weight being greater, they will require a more considerable force to put them in motion than when the chains are separate as in the Menai bridge. The following are the proportions of the several parts of the—

HUNGERFORD BRIDGE.

Height of piers	80 feet.
Distance between centres of piers	$676\frac{1}{3}$,,
Distance between abutments	$1352\frac{1}{2}$,,
Deflection of chain	50 ,,
Size of iron in the links	7 inches + 1 inch.
Length of the links vary with the catenary curves, giving a distance of twenty feet horizontal between two vertical lines, passing through the joint first, giving a uniform distance to all the suspension rods, which are placed two to the length of one of these links, or ten feet asunder.	
Number of links	2600
Weight of links about $5\frac{1}{2}$ cwt. each on an average.	
Diameter of joint pins	$4\frac{5}{8}$ inches.
The quantity of iron contained in the chain at the piers equal in area to	312 sq. in.
At centre of the span	296 ,,
Total weight of chain about	720 tons.
Width of platform	14 feet.
Height above high water in the centre of the span	$32\frac{1}{2}$,,
Weight near the piers	$28\frac{1}{4}$,,
Rise of curve	4 ,,

The chains of the Fribourg bridge are composed of an assemblage of wrought-iron wires formed into a bundle or cable, but not twisted; each cable is composed of twelve strands containing each 56 wires, and eight genious models of a suspension railway and bridge. These models having been introduced to the notice of the public at the time when the railroad between Liverpool and Manchester was approaching its completion, they attracted considerable attention, in consequence of which the inventor, at the solicitation of the proprietor of the "Kaleidoscope," furnished to that periodical the following sketch and description of what he calls the new bar-suspension bridge: —

Fig. 26.



"The above sketch," says Mr. Motley, "is taken from a drawing made on the scale of a quarter of an inch to a foot, which represents a park, or other bridge, of fifty feet span. The horizontal line or beam immediately under the floor is composed of five lengths of wrought-iron, joined by means of vertical standards or supports, with cross bars at the top in the form of the letter T, the arms sufficiently long to admit the beams to be double-bolted, so as to render the joints inflexible. At the top and bottom of the vertical supports is a strong bolt, which connects the two sides of the bridge, to the ends of which are affixed the suspending bars, which are so arranged that, whenever the pressure may be on the bridge, it is uniformly conveyed to the two extreme points at each end, which will readily be conceived by any person the least acquainted with mechanics. The new model which I have made is on the scale of one inch to the foot, and represents a bridge 100 feet span, consequently it is 8 feet 4 inches long, and 12 inches wide. The whole weight of the iron-work is only 11½ lbs., and it has supported upwards of 450 lbs., deflecting only half an inch in the middle. With the addition of about 3½ lbs. more of iron, I think it would bear nearly half a ton weight; thus showing the great advantage of mechanically dividing materials; for if we take a three quarters of an inch bar of iron, eight feet four inches long (which will weigh more than the model), and support it at each end, 28 lbs. will make it deflect more than 450 lbs. did the model. Supposing the model to weigh 15 lbs., a bridge built in that proportion, 100 feet long, and 24 feet wide, having three sets of beams, would weigh not exceeding 20 tons, independent of the railway or fence, which railing or fence, arranged as in the above sketch, would add considerably to its strength and stability, and would, I have no doubt, support, with perfect safety, from 300 to 400 tons, which is considerably more than double the weight it would ever be required to bear, admitting it to be loaded with 1¼ cwt. to every superficial foot. At any rate, I feel confident that from 25 to 30 tons of wrought-iron would make a bridge equal if not superior in strength to the Bristol iron bridges erected by the Jessops, which are 100 feet span, and certainly the lightest and most simple in construction of any cast-iron bridge that I have ever seen, not excepting the Vauxhall one in London. These two bridges cost between 9000*l.* and 10,000*l.*, and contained about 150 tons of metal in each." Thus much of Mr. Motley's description has been retained, as bearing to some extent on the truss-girder system introduced in many of our railway bridges.

The remarkable building, within which the Great Exhibition of 1851 took place, as being the first example of the use of cast-iron on a very large scale for structures of an analogous character, requires some especial notice in a work on metal manufactures.

The site for the building was a rectangular strip of ground in Hyde Park, situated between the Queen's drive and Rotten Row, and contained about 26 acres, being approximately 2300 feet in length by 500 feet in breadth. Mr. Digby Wyatt thus describes the general effect:—

"The principal entrance to the Exhibition is situated in the centre of the south side, opposite to the Prince of Wales's gate, one of the main entrances to Hyde Park. Passing through a vestibule 72 feet by 48, the visitor finds admittance to the main building, and stands beneath the roof of the great feature of the whole, the transept. Above his head, at a height of 68 feet from the ground, springs a semi-cylindrical vault, 72 feet in diameter, which extends for a length of 408 feet from south to north. Advancing about half-way along the transept, the visitor will find himself as nearly as possible in the centre of the building, and from this point his eye may range eastward and westward along its vast nave, for a distance of upwards of 900 feet in each direction, the total length of the building being not less than 1848 feet. The nave is a grand avenue, 64 feet high and 72 feet wide, crossing the transept at right angles. On each side of it extend aisles 24 feet in width; and above them, at a height of 24 feet from the ground, are carried galleries, surrounding the whole of the nave and the transept, so that a complete circuit of communication is carried throughout the whole structure at that level. Beyond these first aisles, and parallel with them, at a distance of 48 feet, are second aisles of similar width, and similarly covered for their whole width with galleries on the same level as those over the first aisles. In order that the public may pass freely from one line of galleries to the other, bridges at frequent intervals span the 48 feet avenues, and at the same time divide them into courts, each of which has been so arranged as to present an *ensemble* to the eye of the spectator looking down upon it from the galleries. The width of 48 feet, which we have described as thus subdivided, and the second aisles, are roofed over at a height of 44 feet from the ground, The remaining portion of the building in width consists of one story only, 24 feet high, in which, of course, there are no galleries. Ten double staircases, 8 feet wide, give access to these galleries."

The vertical supports in this gigantic structure consisted entirely of cast-iron; the horizontal connections and girders were constructed of both wrought and cast-iron. Of wrought-iron, it has been estimated that no less than 550 tons were used, and of cast-iron 3500 tons. The columns were 8 inches diameter, and those on the ground floor were 18 feet $5\frac{1}{2}$ inches high; they were made hollow in order to convey the water from the roof of the building, and the thickness of the metal of which they were composed varied, according to the weight each column was intended to support, from $\frac{3}{8}$ of an inch to $1\frac{1}{8}$: square faces added considerably to the sectional area of the metal, upon the amount of which the strength of the column in a great measure depended.

The building rested on 1060 columns on the ground floor. The extent of the whole of this building may be thus stated:—The total area of the ground floor was 772,784 feet, and that of the galleries, which extended nearly a mile in length, 217,100 square feet. The total cubic contents of the building were about 33,000,000 feet; there were nearly 2300 cast-iron girders, and 358 wrought-iron trusses for supporting the galleries and roof, 30 miles of gutters for carrying water to the columns, 202 miles of sash bars, and 900,000 superficial feet of glass. The width of the nave was, within 10 feet, double that of St. Paul's cathedral, whilst its length was more than four times as great.

This building has become the model for numerous other structures, and is itself perpetuated, with yet greater additions, in grounds purchased by the Crystal Palace Company in Penge Park at Sydenham. The Exhibition now opened (May 1853) at Dublin, that about to be opened in June at New York, and a permanent building to be erected for exhibitions of national industry and other purposes in Paris, have each adopted this combination of iron, wood, and glass, as being at the same time the least expensive, the most easily constructed, and, for these purposes, the most elegant and useful that can be reared.

CHAP. VIII.

ROLLING IRON. — BOILER PLATES. — MISCELLANEOUS ARTICLES.

MR. CORT'S PATENT FOR MANUFACTURING IRON BY ROLLING. — ROLLERS USED AT THE PUDDLING FURNACE. — IRON TRADE AND MANUFACTURE IN FRANCE AND AMERICA. — UNITED STATES' IRON-WORKS. — CAMBRELENG'S REPORT. — BOILER PLATES. — SHEET IRON BOATS, FURNITURE, AND COFFINS.

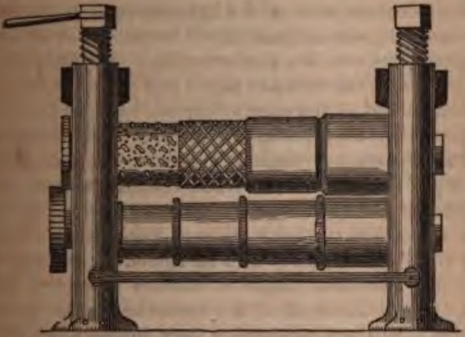
Rolling Iron.

THE art of laminating ductile metal by passing it between a pair of rollers is by no means an invention of modern times, though at what period it began to be practised does not appear. The ingenuity, however, of the last generation of iron masters not only carried the power of the rolling machinery to its utmost extent, in spreading out metallic sheets to the fineness of silk and the flexibility of ribands, but more especially distinguished themselves by its application to the manufacture of native iron in lieu of the forge, which had always been considered as indispensable. At present, therefore, instead of working the bloom of iron under a ponderous hammer, until it is brought to the form of a bar, a process requiring considerable dexterity in the forgeman, the red-hot mass, on being drawn from the puddling furnace as before described, is reduced by being successively passed between massy rollers, which not only expels the heterogeneous matters from the iron, but performs the operation of bringing it into the shape required with incredible celerity, but little ingenuity being at the same time demanded of the workmen. In this, as in some other processes, where slow and laborious courses have been superseded by rapid and easy execution, the article produced by the new method is not, in all cases, and for every purpose, equal to that manufactured upon the old principle. The operation of the rollers neither so completely drives out all deteriorating matter, nor does it so entirely close up the pores of the metal as the long and repeated application of the hammer. On the other hand, the reduction of price arising out of this method, and the adaptation of the material so produced to the great variety of purposes for which cheap iron is required, render the discovery of this system an increasing source of national wealth and industry.

The name of Cort, the individual who introduced to the notice of iron masters the present well-known and important process of puddling, has been already mentioned. In 1784 he specified his improvement on the old method, in the body of a patent by him obtained "for a new mode and art of shingling, welding, and manufacturing iron and steel into bars, plates, &c. of purer quality, in large quantities, by a more effectual application of fire and machinery, and with greater yield, than by any method before attained or put in practice." This project, so unprofitable to the originator, but which under other management has become so extensive and lucrative a branch of our national industry, deserves to be identified with the name of the proposer. For the same reason, the following sketch of the course pursued and the advantages claimed by Mr. Cort, as published in the Repertory of Art, &c. 1795, will be in place here. After having described the puddling process, the patentee proceeds, "And the whole of the above part of my method and process of preparing, manufacturing, and working of iron, is substituted instead of the use of the finery, and is my invention, and was never before used or put in practice by any other person or persons. The iron so prepared and made may be afterwards stamped into plates, and piled or broke, or worked in an air furnace, either by means of pots, or by piling such pieces, in any of the methods ever used in the manufacture of iron, from coke fineries without pots; but the method and process invented and brought to perfection by me, is to continue the loops in the same furnace, or to put them into another air furnace or furnaces, and to heat them to a white or welding heat, and then to shingle them under a forge hammer, or by other machinery, into half blooms, slabe, or other forms: and these may be heated in the chafery, according to the old practice; but my new invention is to put them again into the same or other air furnaces, from which I take the half blooms, and draw them under the forge hammer, or otherwise, as last aforesaid, into anconies, bars, half flats, small square-tilted rods for wire, or such uses as may be required; and the slabe, having been shingled in the foregoing part of the process to the sizes of the grooves in my rollers, through which it is intended to be passed, is worked by me through the grooved rollers, in the manner in which I use bar or wrought-iron, fagoted and heated to a welded heat for that purpose; which manner of working any sort of iron, in a white or welding heat, through grooved rollers, is entirely my own invention. Iron, and also steel, so prepared, made, wrought, and manufactured, by such effectual application of fire and machinery, will be discharged of the impurities and foreign matter which adhere to them when manufactured in the methods commonly practised. The steel is of an excellent quality, and the iron will be found to be good tough iron, in bars and uses whether large or small: and all sorts of merchant iron, whether it be made from metal of a red-short or a cold-short nature; and blistered steel, whether made from iron prepared according to the above process, or from any other iron; when fagoted together, heated to a white or welding heat, rolled in that heat through grooved rollers, according to the method invented by me, and slit through the common cutters, is equal to steel manufactured by forge and tilt hammers. The whole of which discovery and attainment are produced by a more effectual application of fire and machinery, as described by me, than was before known of or used by others, and are entirely new, and contrary to all received opinions amongst persons conversant in the manufacture of iron: and the whole of my method may be completed without the necessity of using finery, charcoal, coke, chafery, or hollow fire; or without requiring any blast, or the use of flues in any part of the process."

Fig. 27. represents a front view of a pair of rollers used in the manufacture of iron in connection with the puddling furnace. They are about four feet long, divided into four parts, the largest being about twenty inches in diameter. That portion of the upper roller under which the metal is first passed, is cut in a deep and irregular manner, resembling that chiselling in stone called moresque work, that it may the more easily get hold of and compress the metal when almost in a fluid state; the plate is next passed under the cross-cut portion of the roller, and successively through the flat sections. The lower roller, it will be observed, is formed with raised collars at intervals, to keep the metal in its proper course. The rollers are connected by cog-wheels placed upon their axes; upon the lowermost of these

Fig. 27.



works also the wheel, by means of which the revoluti is communicated. The cheeks are of cast-iron, ve massy, that they may bear the violent usage to whi they are subject.

The peace of Europe, and the free intercourse whic has been so long allowed between Great Britain and othe countries, has led to the introduction of this improve ment in the making of iron, as well to the continent a into America. In the year 1812, the celebrated Frenc chemist, M. Collet Descostils, excited the attention of hi scientific countrymen to the importance of their nativ iron ores, by the analysis which he published of some English specimens of a similar quality. Dr. Colquhoun, in the elaborate dissertation on the argillaceous ore of iron, communicated to Brewster's Journal, before referred to, notices with approbation the researches of Descostils, and alludes more particularly to one important deduction from the labours of the French chemist, namely, that "although the specimens of iron ore examined by him had been collected from different localities in France, and also from England, they all agreed in one respect, that they had been found in districts abounding with coal." And the whole of his researches led to the conclusion, that there subsisted a very intimate geological connection between coal and the argillaceous carbonate of iron; a connection so close, that the miner might almost with certainty regard the presence of the one mineral as a proof of the vicinity of the other. But it is difficult to overcome the force of a rooted prejudice. Although the memoir of Descostils must at once have carried the conviction to the minds of men of science, that the mos useful ironstone was co-existent with the beds of coal i the various coal districts of France; yet the nation a large for a long period refused to believe that they pos sessed such a treasure within themselves, and obstinatel persisted in regarding the island of Britain as the envie and exclusive depository of that ore. Even after man of the *élèves* of the Ecole des Mines, stimulated to re search by the discoveries of Descostils, had verified a his views, and reduced his opinions to certainty, it still continued to be maintained, that the ore on which they made their experiments did not properly represent any strata, or masses of materials, sufficiently extensive to be of importance in a national point of view. But, in a matter of such moment to their country, the most eminent chemists and *ingénieurs des mines* in France were resolved that truth should prevail over prejudice; and it is perhaps to the existence of this powerful prejudice that at least one good effect is to be traced, since the investigations of her men of science have procured for France, where the art of metallurgy is yet in its infancy, the best account at present extant, both of the chemical constitution and also of the general history of the argillaceous ironstone. The fact at least is undoubted, that within a small number of late years there have been published in France a large number of analyses of various specimens of this ore, although there do not appear to have been many similar notices printed in any other country. The French, however, have, subsequently to the period above alluded to, not only imported our workmen, but our discoveries. So long since as 1819, it appeared from a statistical report that France consumed annually about 1,000,000 of metric quintals of forged iron in large bars; and that the manufacture of these required about 300 forges of the construction which had been for ages followed in that country; but, by the superior mode long adopted in Britain, and well known in France since the last peace by the appellation of *forge à l'Anglaise*, (refining in a reverberating furnace with pit coal, and forming into bars by laminating rollers,) twenty manufactories could have done the work of these 300. So rapidly, however, have the French availed themselves of a knowledge of our manufacturing processes, that they have established as many iron manufactories on the British plan as are nearly sufficient to supply all the bar-iron consumed in France.

With reference to the United States, it is well known that forges with the most perfect machinery, and ironstone of a capital quality, co-exist in various sections of the country. Of these, as perhaps the most noted, may be mentioned the Franconia iron-works, which are situated 140 miles N.N.W. from Boston. There are two manufactories, the New Hampshire Company, and the Upper Works. The ore is nearly four miles distant from both, and costs them, delivered at their works, 4 dollars 75 cents (20*s.* 5*d.*) per ton: it yields 50 per cent. of pig-iron, and 30 per cent. of bar-iron. They (the two works) manufacture at present 300 tons of bar-iron, and 300 or 350 tons of cast-iron annually. Bar-iron is worth at Franconia 112 dollars (24*l.*) per ton, and pig-iron 40 dollars (8*l.* 12*s.*) per ton. The works of the New Hampshire Iron Company form much the largest establishment, consisting of a blast-furnace, forge, trip-hammer, shop, and mills: it employs sixty men in the various departments of mining, coaling, smelting, and forging, the operations of the trip-hammer, shop, and mills, farming, &c. Their furnace, which is like those employed in the great iron mines of Sweden, is thirty feet in height, of an ovoidal form, and furnished with a powerful cylindrical machine for giving the blast. It is lined with white granite, composed principally of felspar, which, we were told, formed a very durable and excellent lining. Considerable expectation was excited respecting the discovery of fossil coal, said to exist twelve miles distant: this, it seems, was anthracite, or stone coal; but the author observes, "It is not likely to be of any use in making iron, since all attempts of the kind have hitherto proved unsuccessful." Time and experience has taught the Americans a method of using their "stone coal;" and although formerly denounced by the iron smelters in general, what is by the workmen termed *blind coal* is used in the smelting establishments in the south of Wales with great advantage.

It is a fact curiously illustrative of the conduct of Great Britain, nearly a century ago, towards that country which is now taking such immense strides of actual rivalship, that in 1750, parliament, under the advice of the Board of Trade, prohibited the erection of rolling and slitting mills and other ironworks in the North American provinces! Such, however, is the demand for English iron in the United States, that its introduction to an immense amount was only counteracted by a heavy duty. That the operation of such an impost, however important as a bonus to the native iron smelters, should have been considered a grievous disadvantage to the general manufacturer, will not be surprising when we find that these manufacturers are told by their countryman Cambreleng, in his celebrated report on commerce and navigation, delivered in 1830, that while "they of necessity consume sheet, hoop, bolt, rod, and bar rolled iron as raw materials, with which the Birmingham manufacturer is supplied at from 30 to 50 dollars per ton, the American duties vary from 37 dollars per ton to 3½ cents per pound, or 78 dollars 40 cents per ton, or from 123⅓ to 156⅘ per cent. *ad valorem*. In other words, the effect of our own law is to give a premium to the hardware manufacturers, blacksmiths, &c. &c. of Great Britain, equal on an average to 57 dollars 70 cents on every ton of iron manufactured in that country, for the use of the United States. The actual price of these raw materials in Great Britain are 30 to 50 dollars, and in the United States 75 to 180 dollars per ton. The duty on 15 pounds of sheet and band iron for fender plates is 52½ cents; the duty on the article when manufactured, is only 23 cents; on 20 pounds of sheet-iron for grate pans, 70 cents; on the manufactured article, 18¾ cents; on 100 pounds of sheet-iron for stove-pipes, 3 dollars 50 cents; on stove-pipe manufactured, 68¾ cents. The duty on hardware generally is 25 per cent., while the duties on the various kinds of English iron used in manufacturing, average about 140 per cent. *ad valorem*, giving more than 100 per cent. premium to the English manufacturer."

The whole condition of our iron trade with America has been changed since this was written; and it is only now retained as an incident in the history of iron manufacture.

Boiler Plates.

Rolled iron, of various degrees of thickness, is at present used for an almost infinite variety of purposes in the home manufactures of this country. Not merely as entering into the construction of articles which are required to withstand the effects of fire, but to a vast extent as a substitute for wood, is the consumption of iron in this state carried on. The strongest kind, generally speaking, is that in which the plates are rolled for the manufacture of steam-engine boilers; and varying from five eighths to a quarter of an inch, or less, in thickness. These plates, weighing sometimes one cwt. each, are, on coming from the rollers, cut into the sizes required by immense shears, moved by water or steam power; and the facility with which shreds are clipped off the edges of a plate of iron of this description, exhibits in a striking manner the power with which ingenuity has invested the workman in the management of so obdurate a material. The plates for spherical boilers are swamped into the desired form by means of hammering while red-hot, in concave blocks of cast metal; and, upon the surface of similar blocks, gores, of all the various shapes as to flexure, are produced.

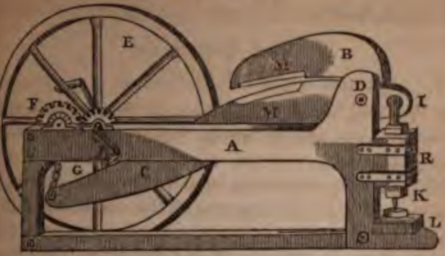
The holes, by means of which the plates are riveted together with iron studs, are punched in the metal by the assistance of what the boiler-makers call a *lever fly*. This machine, so simple in its construction, and yet so efficient, is represented in *fig.* 28.

A is the front side of a massy cast-iron frame, and B the upper part of the other side, which is cast very stout.

C is the lever, eight or nine feet in length, working between the two sides of the frame, upon a thick bolt, at D.

E a heavy fly wheel, about eight feet in diameter,

Fig. 28.



having handles on both sides, that it may be turned by three or four men: its axis contains a cog wheel, six or eight inches in diameter, working in another cog wheel F, which is about four times the diameter of the former. The axle of the last-mentioned wheel contains a crank, upon which the lever is suspended by the strong chain G.

R is the head gear, consisting of an iron box, through which works a square piece of iron, tackled to the lever at I, and into which is inserted the punch at K.

L indicates the boss, in which is fastened a steel die, perforated exactly to suit the thickness of the punch. Thus it will be readily comprehended how, by turning the wheel so as to put the lever in motion, the punch will be slowly inserted and withdrawn from the die, and the plate perforated by being placed within its operation.

M M are two cutters of steel, which some persons have inserted in grooves properly formed, and by means of which the machine may be likewise used as a pair of shears.

The plates being properly shaped and bent to the design of the boiler intended to be made, and holes pierced in the corresponding edges at equal distances, the rivets are inserted when red-hot, and are driven home and clenched by two men with hammers, working with alternate strokes, one from within, and the other on the outside of the boiler.

Sheet Iron Boats.

We have now applied sheet-iron so very extensively, that much of what follows may appear superfluous; but as showing the idea of using iron boats in 1836 it is important.

Not only has sheet-iron been manufactured into small waggons, and the corves used at the collieries, but likewise into vessels for the navigation of our canals. Numbers of these curiosities, of various sizes, may be seen afloat, at different places, especially in the neighbourhood and employment of ironworks. A few years ago, a steam-boat of sixty feet keel, nine feet beam, three feet high, and composed entirely of cast-iron, was constructed at New York, as a passage-boat for navigation on the Susquehana river. The whole weight of the iron in the boat was about 3400 lbs., and of wood in the decks, cabin, &c. about 2600 lbs.; altogether about three tons: or, including the steam-engine and boiler, the entire weight was but five tons. Could Columbus, or any of the crew who sailed with him in the discovery of America, be permitted to meet this vessel on her passage between Colombia and Northumberland in the United States, it is not easy to say whether they would be most astonished at the rapid progress of the vessel without sails or oars; or the discovery that the whole was a mass of iron equal in weight to three or four of their anchors, and yet floating in the water like a cork, in a draught of five inches.

Within the present year (1831) an elegant and swift passage-boat, of the description above mentioned, and called the *Rapid*, has been built by Mr. Wilson, Tophill, Scotland, and launched into the great canal. She is composed of the best malleable iron, and is fitted up in a style of neatness and comfort that far excels any boat of the same construction in Scotland. She is sixty-six feet in length, and six feet in breadth on the beams.

Her whole weight is scarcely two tons and a half. She carries sixty cabin and steerage passengers, and goes at the rate of ten miles an hour; so smooth is her motion that the passengers feel as easy as in a parlour. Three horses are employed to drag the Rapid, and there is a fresh relay every six miles. She draws, when unloaded, nine inches of water, and when filled only fifteen. The committee of the great canal made a first trial of her powers, and were highly pleased with the experiment. The distance from Tophill to Port Dundas is twenty-four miles, and was accomplished in two hours and forty-five minutes; but deducting the detentions at locks, &c. made the exact speed ten miles an hour. She is fitted up in manner fully equal to the interior of a coach, and is well lighted and airy, the windows being fitted to slide in the coach fashion; and the cabin, which will contain thirteen passengers, is handsomely tapestried, and fitted with comfortable elbow chairs. The small ladies' cabin, steward's room, and steerage, are very compact, and well arranged, and it is a matter of surprise how every thing has been so suited as to give the passengers all the advantages of a pleasure-boat.

The following statements of the advantages of iron in ship-building, and the extent to which it is now employed, will, with the account of the Britannia Bridge, place the subject clearly before the reader.

The use of wrought iron in the construction of ships, is one of the modern introductions which may be regarded as of the utmost promise.

The value of iron, in addition to its lightness and strength, in the construction of vessels, was severely tested in the case of the Great Britain, and in the Prince of Wales iron steam-vessel, in the launching of which an incident occurred which is thus described:—

"The vessel is entirely of iron, and is intended for the Margate station; she is 180 feet long between the perpendiculars. In launching, the cleet on the bow gave way, in consequence of the bolts breaking, and let the vessel down so that the bilge came in contact with the wharf. She was ultimately forced off by screw-jacks and two tug vessels, cutting her way deeper into the concrete and planking of the wharf, until she assumed a position resting against the sea wall; and at that period the distance measured from the face of the wharf to the point of contact of the vessel and the surface of the water, was 110 feet. The whole of the deck in the centre of the vessel was left unfastened for the reception of the machinery. When completely afloat, it was found that the shear of the vessel was not broken, and that she had received no injury, except that the bow was twisted in consequence of letting go the stern-rope, and thus exposing the vessel to the sweep of a strong ebb-tide. On examination, it was found that three of the angle iron ribs or frames were broken, and one of the plates cracked, occasioning a considerable leak, which was accompanied by no other inconvenience than that of filling the bow compartment as far as the first bulk-head; and after hauling the vessel into dock, the necessary repairs were effected in four days."

The success attending the construction of ships in iron has been so great, that there is now being constructed at the Clyde a steam-vessel considerably larger than the Great Britain; and thus she will be, when launched, the largest vessel afloat. Her name is the Atrato. The entire length of the keel of this vessel is laid (1853) resting on blocks: this enormous bar is in nine pieces, joined by scarf-joints, and firmly riveted together. The sternpost is in one piece, and so is the stern, which runs for about ten feet into the horizontal keel. The stern alone weighs 65 cwt. Only one-half of the ribs or frames are yet in place; and even with the long length of bare keel, terminated by the stern standing up some forty feet or more, the enormous dimensions of the vessel can hardly be appreciated. The Windsor Castle, building at Pembroke, is said to be the "largest vessel in the world;" her size, and that of the

Atrato, will place the enormous size of the iron ship in the clearest light:—

WINDSOR CASTLE.

	feet.
Extreme length of keel - - -	278
" " keel and forecastle -	240½
Breadth of beam - - - -	25
Depth of hold - - - -	24

THE ATRATO.

	feet.
Extreme length of keel - - -	310
" " keel and forecastle -	340
Breadth of beam - - - -	52
Depth of hold - - - -	34

Superior even to these gigantic undertakings which man has attempted in iron, the enormous wrought-iron tubes of the Conway and Britannia tubular bridges far exceed anything which has gone before them. The general character of both the Conway and Britannia tubes may be gathered from the following description: —Each line of the Britannia bridge consists of a single tube, 1511 feet in length, weighing 5270 tons; and, with the exception of the permanent way in the interior, consisting entirely of wrought-iron and cast-iron, viz.

	Tons.
Wrought-iron - - -	4,680
Cast-iron - - - -	508
Permanent way - - -	82
	5,270

The cast-iron is entirely confined to those portions of the tube which pass through towers. This immense beam is supported in five places, viz. on the Britannia tower at the centre, and on each of the side towers at 460 feet distance on either side, and on the abutments, at a distance of 230 feet from the side towers. The clear span of the Conway bridge is 400 feet, or 60 feet less than the Britannia. It is securely fixed in the centre tower, but its bearings in the side towers and abutments are moveable, that it may expand and contract from changes of temperature without resistance. The following general summary of the important points in the construction of the Britannia bridge has been given by Mr. Edwin Clarke. The weight of a single line, and the number of rivets, together with the sectional areas at the centre of the large tubes, are as follows:—

	Weight.	Sectional Area.	Number of Rivets.
	tons.	square inches.	
Top - - -	1481	648·25	310,390
Sides - -	1727	302·22	535,650
Bottom - -	1472	585·43	249,010
Total - -	4680	1535·68	1,095,050

The entire bridge, including both lines, contains nearly a million and a half cubic feet, or 105,000 tons of masonry, 44,200 cubic feet, or 9480 tons, of wrought-iron, and 1988 tons of cast-iron.

The two tubes in their complete state contain 9360 tons of wrought-iron, 1015 tons of cast-iron, and 165 tons of permanent way.

This immense tube must be regarded as a perfectly rigid hollow beam of iron. The top and bottom of the tube has a cellular structure, the partitions placed perpendicular to the horizontal plates being boiler plate iron, placed on its edge, thus offering the utmost possible degree of resistance. The vertical sides of the tubes are composed of single plates riveted together, the firm connection between the sides and the top and bottom being secured by angle pieces of cast-iron. The deflection occasioned by the passing of a heavy train of carriages is exceedingly small—far less indeed than that which arises from the action of the sun on one side of the tube.

For the details of this extraordinary work, the reader is referred to Mr. Edwin Clarke's work on *the Britannia and Conway Tubular Bridges*, and Mr. Fairbairn's

Conway and Menai Tubular Bridges. Both of these works may be consulted with advantage by all who are interested in the employment of iron in construction. The experiments in particular of Mr. Eaton Hodgkinson are of the utmost value.

The following statement of the span of some of the finest bridges in the world, will convey information as to the relative proportions of these and of the Conway and Britannia tubular bridges:—

	Material.	Span of Centre Arch.	Rise of Arch at Centre.	Engineers.
		feet.	feet.	
Sunderland, over the Wear	cast-iron	240	30	Wilson.
Southwark Bridge - -	,,	240	24	Rennie.
Dee Bridge, Chester -	sandstone	200	42	Hartley.
Pont du Carrousel over the Seine - - - -	cast-iron	187	15⅛	Polonceau.
High Level Bridge, Newcastle - - - -	,,	138·10		Stephenson
London Bridge - - -	granite	152	29½	Rennie.
Maidenhead Bridge over the Thames - - -	brick.	128	24¼	Brunel.
Conway Tubular Bridge -	wrought iron	400		Stephenson.
Britannia ,, ,,	,,	460		,,

Sheet Iron Coffins.

In the year 1809, a gentleman of Birmingham suggested the employment of iron as a substitute for mahogany and other costly woods, in furniture, and the furnishing of houses. He recommended, that bedsteads, the posts of which as well as the frames might be hollow, and the form might be beautifully wreathed with flowers, &c. or embossed with fanciful ornaments, chests of drawers, bookcases, and bureaus, might all be made of sheet-iron. Such furniture, it was contended, would be cheaper than articles of mahogany, not heavier than wood, though more beautiful; and, exclusive of the convenience of removal, it would afford great security against fire. Although there are various obstacles in the way of carrying out practically this project of the Birmingham speculator to so great an extent as he anticipates, yet iron bedsteads are both common and useful; and, what is more remarkable, not only has the mahogany of the frame been in many cases superseded by iron, but even the feathers themselves!—"iron mattresses" having obtained considerable vogue among travellers. Spring cushions are now commonly used.

One of the most singular applications, however, of sheet-iron which our times have witnessed, has been its use in the construction of that piece of furniture of man's *ultima domus*, which is usually furnished by the undertaker. This forms a curious episode in our history, although the sheet-iron coffin has never been generally adopted. In the year 1819, a patent was obtained by an individual of the name of Bridgman, for making coffins of rolled iron: this novel introduction of the material was defended as being better calculated than wood for the protection of the bodies therein deposited, from sacrilegious abstraction for anatomical purposes. The reception, however, of these iron coffins into the metropolitan cemeteries was withstood, on the ground that, as they would last much longer than wooden ones, the graveyards consecrated for the sepulture of the inhabitants of the different parishes would soon become too strait for their accommodation. In order to try the legal validity of this objection, Bridgman, the patentee, made application at the burial-ground of St. Andrew's, Holborn, to bury the corpse of a woman in an iron coffin: the funeral proceeded to the ground in Gray's Inn Lane, but the interment was withstood by the parish authorities, the coffin deposited in the bone house, and legal proceedings instituted against the churchwardens. This novel case was argued in the consistory court, the most eminent counsel being employed on both sides.

In favour of interment in iron, it was contended, that sepulchral chests were of great antiquity; that coffins of stone and lead, as well as wood, had been, or were, in use in this country from very early times, and that even brick graves were every day allowed to be made in all churchyards throughout the kingdom. The question to be argued, therefore, was one of right, the law not having either specified or prohibited any particular material. On the part of the churchwardens, it was alleged, that the right of the parishioners generally would be greatly infringed by the introduction of iron coffins, as the ground would soon be entirely occupied by them, and, consequently, an act of injustice would be committed. The judge, sir Wm. Scott, in a luminous summing up, observed, that with reference to precedent it was a well-known fact, that burning the body, and naked inhumation, preceded the use of coffins of any sort; and that among nations civilised as well as savage: and it was remarkable that in the burial-service of the church there was no mention made of a coffin at all. It was asserted by one party, that, in point of absolute duration, the iron coffins would not last longer than wooden ones. The learned judge remarked, that, upon this point, it was not without a violent revolt to all the ideas he had formed on the subject, that he heard it affirmed, that coffins formed of iron would not keep longer possession of the soil than those formed of wood: to him it appeared, without pretending to any experimental knowledge on such subjects, that it must be otherwise; rust was the process by which iron travelled to decomposition; excluded from the air, it remained unimpaired; and if it did from internal moisture, or any small admission of external air, contract rust, that rust, until it scales off, protects the interior parts from further decay; whereas wood corrupts internally, and thus hastens its own destruction. It was ultimately decided that the parish should prepare a table of fees applicable to the reception of iron coffins.

Miscellaneous Articles.

The use and value of rolled iron in the manufacture of an immense variety of small articles are almost beyond conception — certainly beyond enumeration. Wolverhampton and its neighbourhood abound with establishments for the conversion of this convenient material into those neat and economical wares which have become so common in every family. Among these articles, trays, and waiters, varying in size from a snuffers-dish of a few inches in length, to the plateau sufficiently large to hold the entire tea equipage of a numerous party. These universal requisites are either simply painted or varnished, or, as is most commonly the case, they are japanned with a most beautiful and durable ground, upon which are laid colours and gilding with so much taste and effect, that the individuals who execute these designs deserve more praise than is usually given to them, for workmanship assimilating so closely with some of the more celebrated productions of the fine arts. The method of japanning wares of this description, originally taken up by the Birmingham manufacturers almost as an invention suggested by their peculiar staple, has now, through the combinations of science and long experience, attained a high degree of perfection. No place in the world can indeed rival the artificers of this famous emporium in the degree of elegance and finish, presented by many of the more expensive fabrications, the body of which consists of a few pennyworths of rolled iron.

The facilities which experience and improved machinery have introduced into the manufacture of this sort of japanery, have long since placed most of these products of the Birmingham workshops within the reach of the humblest housekeeper. To such persons as those who perceive nothing but signs of national decay in the extent to which the elegant and economical wares of Wedgewood have superseded pewter plates, wooden trenchers, and brown clay crockery upon the shelves of mechanics and labourers, the appearance of the articles above alluded to may [illegible] other than pleasing associations. To others, [illegible] calculate more rationally [illegible] ovement, it will be no gr[illegible] hat almost every family [illegible] s deem it decent, especially on visiting occasions, to place their cups and saucers and other paraphernalia upon a

> "Tea-board with caddy, which are duly placed,
> When out of use, to show the owner's taste,
> Snug on the shelf; or, should the wife be able,
> Behind a fender on the parlour table."

The larger sorts of trays are formed either by stamping them at once in massy dies of metal, the faces of which are hollowed out to the shape and size required; by swaying the edges with hammers; or most generally, especially in the better sorts, by turning up the margin on a block, and jointing the corners either by means of solder or rivets, and then wiring the edge in the manner adopted in the manufacture of tin utensils in general: by this means the article is not only rendered more firm and useful, but its beauty of appearance when finished much increased.

Besides these elegant and highly prized wares, an inconceivable diversity of pans, boxes, buckets, baskets, scrips, &c. are now found in every hardwareman's stock, the body of which consists of iron reduced to sheets between smooth laminating rollers. A large proportion of these utensils are fabricated by merely connecting the edges of the metal, where requiring to be fastened, with overlapping the margins, or at most by the means of a few rivets; thus by the simplest contrivances, and from one of the cheapest materials, ingenuity forms innumerable articles, which, when neatly varnished, are as handsome as they have become indispensable.

CHAP. IX.

IRON PLATING, AND ROAD RAILS.

SPADES AND SHOVELS. — PLANTATION TOOLS. — GROOVED ROLLERS. — FAGGOT IRON. — COMPARISON OF HAMMERED AND ROLLED IRON. — SLITTING. — IRON TUBES. — IRON ROAD RAILS. — BIRKINSHAW'S PATENT. — STEPHENSON'S REPORT. — LIVERPOOL AND MANCHESTER RAILWAY.

THE persons engaged in the business of rolling iron heat the slabs red hot in an air furnace, and in this state pass them between the rollers; a boy, being stationed on the further side, catches the plate immediately on its emerging towards him, with a pair of tongs, and when completely delivered, he hands it over to the roller man, who in turn reinserts it for further reduction, having meanwhile diminished the distance between the upper and lower roller, by turning a screw, working upon collars over the former. During the process, by repeated heating and compressing, the sheets are covered with scales; to detach these, and keep the surface the more smooth, the sheet, when drawn from the furnace, is skelped upon the floor, or on an iron plate, and by this means much of this crust is removed.

Spades and Shovels.

The operation of *plating*, as it is called, in the manufacture of spades and shovels, and which was formerly done almost exclusively by the forge-hammer or *skelper*, is now expedited in the greater part of these articles, especially those of the cheap class, by the assistance of the rollers.

The formation of these well-known implements is a trade furnishing employment and subsistence to a numerous body of workmen, as well at Sheffield as at and in the neighbourhood of Birmingham, and in various other places. These articles are made of iron throughout the greater part of the body, the edge or cutting portion only being composed of steel. The bars used for the purpose of making rolled spades consist of the common material supplied by the Staffordshire forges; they are three inches wide, and about half an inch in thickness.

In the manufacturing process, one of these bars is, in the first place, cut into pieces about nine inches in length, and these are again cut in two transversely in the middle. The oblique ends of each piece, after being heated, are driven towards the middle, and by two hammermen, a maker and a striker, they are drawn out on the anvil into what are ultimately to become the cheeks or straps of the shovel. In this state the pieces are nearly in the shape of a child's shuttlecock board. Two of these are then laid exactly together, and a bit of plate steel about an inch wide is placed between them at the square end: the whole now is inserted in the fire until by the operation of the bellows it has attained to a welding heat; it is then placed on the anvil, and by means of a sledge-hammer the two metals are firmly incorporated at the end, and likewise united along the sides; the middle inside, where the handle is to be inserted, being kept open by the driving of an iron chisel down between the straps. In this state the article is ready for the rolling mill. To perform this operation the metal is as usual repeatedly heated, and passed while red hot between the rollers, the only care particularly required being to prevent the ears or straps from cohesion in consequence of repeated or over heating. On this account sifted cinders or dirt is introduced suddenly between the straps with a skimmer, when the iron is heated previously to the first passing of it through the rollers: it will, however, sometimes happen after the best care that some degree of welding takes place.

The common descriptions of iron which admit of being wrought in this manner without difficulty, would not by any means endure the strokes necessary in plating with the skelper, but would be fractured and spoiled by the beating. A better kind of material, therefore, is used when spades or shovels are to be spread out, as the best sorts are, under the tilt hammer. It will be obvious that, besides the general superiority of the iron, hammered shovels possess a decided advantage over those that are rolled, in adaptation to the purposes for which they are generally used. The former sort when properly managed are gradually reduced in thickness from the straight to the convex or cutting edge, while the latter can only be of uniform strength throughout, or very nearly so. In digging, or performing any work where the spade is required to *cut*, the difference between a rolled and a hammered article is very important to the labourer; while for the mere purposes of *shovelling*, where the absence of this wedge form may be largely compensated by the general lightness of the plate, the reasons for preference between the two sorts are almost neutralised. The steel, it will be observed, extends but partially through the extent of the bit, but in general to a sufficient distance to allow the article to be worn down in a reasonable manner.

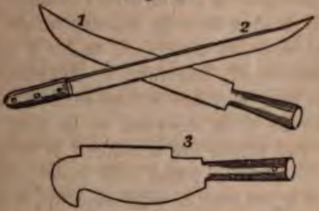
In this stage, in consequence of the heat and flattening, whether by the forge or the rollers, especially the latter, the surface of the plate is covered with a thick scale: to remove this, as well as to stiffen the metal, it is heated and hammered smartly on the anvil, water during the operation being frequently skimmed upon the surface to displace the scales. Sometimes when one of these red hot shovels is brought from the hearth and placed on the wet anvil, on being struck with the great hammer a report like that of a gun takes place.

The article being thus hammered, is next pared with shears to the shape required, after which it is swaged or turned up at the edges, &c. the hollow socket for the shaft opened by means of the hammer and a few other subsidiary tools at the anvil. The shafts are generally made of ash, either bent or sawn into the shape required at the fitting end, while upon the other is formed the crutch or open handle, according to preference. The large "Devonshire shovels," when made for exportation, are delivered without shafts, by which means they are much less cumbersome than the others, which are generally sent abroad or furnished to the home market in a completely finished state.

Plantation Tools.

There is another class of heavy plate-iron articles, properly the production of the forge, and in the exportation of which, under the designation of plantation tools, an amazing trade is carried on between this country and the colonies. These tools consist of matchets, canebills, and hoes: the former are large knives or cutlasses, either in shape similar to No. 1. *fig.* 29. below, about twenty inches long, two inches broad, and the handle formed by turning up the iron in the manner of a tube; or they resemble No. 2. *fig.* 29. twenty-six inches in length, with a wooden scale-haft, like a bread knife.

Fig. 29.



The canebill, No. 3. differs, it will be seen, not much from the common hedging bill: it is, of course, double-edged, and the handle consists of a stout socket, formed by welding the iron, as in the case of the matchet above described. The hoes are of three sorts, including various sizes: 1st, the East India grubbing-hoe, which is long and narrow, somewhat like an adze; 2d, the West India hoe, which is much larger, being nearly the width of a small spade; and 3d, the Carolina hoe, which is larger still, and formed like an inverted shovel. They have each a stout eye, or loop, at the top for the reception of the handle. Formerly these hoes were largely manufactured by the Sheffield edge-tool makers, and fetched good prices; latterly, however, in reference to these implements, that town has been somewhat supplanted, in the estimation of the merchants who trade to the colonial markets, by the smiths of Staffordshire, who furnish the goods on such terms as almost to preclude competition.

They are wrought by means of a forge-hammer, or skelper, in the same manner as shovels; and unfortunately, like some of the latter articles, look very highly as to workmanship, when in reality they are exceedingly little worth. There ought, at least, to be a little steel on the edge; but they have actually, for the sake of cheapness, been ordered and manufactured entirely of iron! The implements are unwieldy enough at best, and such as few persons in this country would like to be compelled to use, day after day, under a vertical sun: there was little need, therefore, to deteriorate the efficiency of the hoe, or rather to deprive it of its edge altogether. But in tools designed to be used by persons whose time and labour are accounted of no great value, and whose comfort is rated still lower, excellency of material, and superiority of workmanship, weigh nothing in the scale against cheapness and cupidity.

Some years ago we saw, in the hands of the inventor, an implement, certainly of most ingenious construction, but which, had it found its way to the plantations, and met with the approbation of the colonists, would have been more to be deprecated than even the steelless articles already noticed. It consisted of a spade, hoe, and mattock on the same shaft: the two latter were of one piece, turning on an iron joint at the extremity of the shaft, and opening out as represented in *fig.* 30. When to be used as a spade merely, the mattock was depressed into the cavity cut for its reception on the upper surface of the shaft, in which situation it was detained, and the tool made firm for use by pushing down over it a stout iron tube, which was used in like manner for the purpose of fastening the mattock hoe.

Fig. 30.

Grooved Rollers.

The use and importance of rollers are by no means confined to the process of flatting metal into sheets or strips for the manufactures already mentioned, and others of a like kind, including wheel-tire, iron hooping, &c., in the formation of which, at the rolling-mill, a prodigious saving is, of course, effected, compared with the expense of bringing the material into the same state with the hammer.

Iron that has been worn out, or *old iron*, as it is commonly called, is most generally re-manufactured into the sorts above mentioned. The metal for this purpose is collected by the smiths and others all over the country, but most largely in London and the sea-port towns, by a class of persons calling themselves "dealers in marine stores." By these dealers it is assorted into three parcels for sale: 1st, *coach-tire*, as they designate the worn out wheel-tire, or other material of like strength; 2d, *bushel-iron*, or the fragments of old hoops, and all pieces of similar size; and 3d, *scrap* or *nut-iron*, consisting of old screws, nails, knobs, and the smaller lumps and pieces in general.

These are at the forge made up into faggots on the bundling bench, in the following manner:—Two standards of iron, in form somewhat resembling the letter U, only square at the bottom, are fastened on the bench, at the distance of a foot or more from each other. In the space between these uprights are laid across the bench two bands of soft iron, about a quarter of an inch square; and over these, pieces of the old hooping properly straightened and cut into lengths, so as to form a foundation; upon these are placed similar pieces to form sides, the interior being filled with bushel-iron or scraps; the top is then, in like manner, covered with flat pieces, after which the iron bands are brought over the faggot and firmly twisted together.

The faggot thus prepared is then inserted in a wind-furnace, and when brought to a welding heat, it is withdrawn, and formed into a bloom by being passed between the large rollers already described. It is then heated again, and passed between other rollers, which are grooved on the surface in ruts or spaces, according as the metal is intended to be reduced to the strength of wheel-tyre, hoop-iron, or different sized bars.

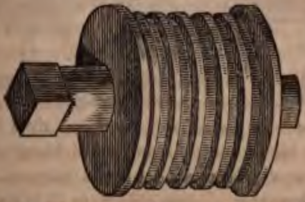
There are in most of the iron-mills sets of rollers, with every variety of corresponding grooves and surfaces. These pairs of rollers are generally placed so as to range in a line with one another, their evolutions being effected or suspended by the means of coupling boxes fitted to the square projecting part of the approaching axles.

This arrangement affords the simplest and most ready method of throwing the rollers into or out of gear, as it is termed; but as it causes, at the same time, through the effect of torsion, the rollers farthest from the first mover to work with much greater stress than those that are nearer, the former are used for the lighter operations, and the latter in those processes where the greater degree of resistance is required to be overcome.

M. Lagerhjelm, who made experiments on rolled and hammered iron with very complete and powerful apparatus, mentions the following results:—" Rolling always gave to the same iron the same uniform density. Hammered bars of the same iron are often of different densities, and frequently contain scales. Rolling does not twist the fibre of the bar as hammering sometimes does. The measure of elasticity is the same for both hammered and rolled bars; but the limit of elasticity (measured by the greatest weight that the bar can support, for a given sectional surface, without any permanent change of form,) is greater for hammered than for rolled bars: if neither have been refolded, the limit of elasticity is increased, and becomes the same for both. Rolling gives more ductility to iron than hammering. Cohesion appears independent of the process employed, and is the same for both. The cohesion is the same for brittle as for soft iron, fibrous, or not fibrous; so that the absolute strength of iron appears to depend upon its ductility. The volume or bulk of the metal increases as the bar is drawn asunder; and the specific gravity of the iron at the broken surface is less, by nearly 0·01, than that of the same iron taken from an unaltered part of the bar. When the iron is stretched, preparatory to its fracture, heat is evolved: the heat is greater for soft than for harsh iron. Sometimes a bright spark appears at the moment of rupture."—*Bulletin Universel.*

The practice of slitting, as it is termed, sheets of metal into light rods, either for the use of the wire-drawers, nail-makers, or for other purposes, has long been known as a succedaneum to the more tedious courses of forging or cutting it into shreds with shears.

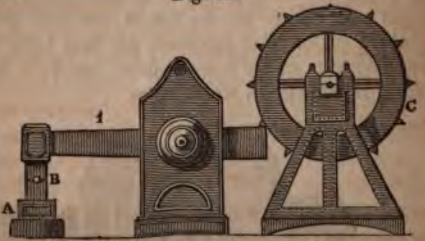
Fig. 31.



This method consists in the adaptation of two pretty large steel *rollers, each channelled* circularly, as represented in *fig.* 31. These are so placed that the cutter or raised parts of one roller, which are exactly turned fo that purpose, shall work in the corresponding channe of the other roller, thus forming what may be calle revolving shears — for the principle is that of clipping: s that a sheet of metal, on being passed through this machinery, is separated into slips agreeing in size with th divisions of the rollers. It will be clear that, by turnin in the surface of the rollers semicircular grooves, instea of square channels, and making the grooved surfac exactly to correspond, round rods of iron, such as a used for palisadoes, wire, and a variety of other pu poses, may easily be produced. In fact, the rollin machinery is largely applied in the manufacture of th description of iron.

A less obvious application of the rollers has latter been attempted in the construction of *tubes* for gas an other purposes, and for which a patent has been grant to Mr. Russel, of Wednesbury. In this process, pla iron, previously rolled to a proper thickness, is cut in such strips or lengths as may be desirable, and in bread corresponding with the width of the tube intended to formed. The sides of the metal are then bent up wi swages in the usual way, so as to bring the two edges close together as possible. The iron thus bent is th placed in an air or blast furnace, and brought to a wel ing heat, in which state it is withdrawn and plac under the hammer. *Fig.* 32. A is the anvil, havin

Fig. 32



block or bolster, with a groove suited to and corresponding with a similar groove, B, in the face of the block: C is a wheel with projecting knobs, which, striking in succession upon the iron-shod end of the hammer shaft, cause it to strike rapidly on the tube. In this process, the tube is repeatedly heated and hammered, until the welding is completed from end to end. A maundrell may be inserted or not during this operation. When the edges of the iron have been thus thoroughly united, the tube is again heated in a furnace; and then passed through a pair of grooved rollers similar to those used in the production of rods, *fig.* 33. Suppose a tube, D, to be passing through these rollers, of which *fig.* 34. represents a cross section, immediately upon its being delivered from the groove it receives an egg-shaped core of metal fixed on the extremity of the rod E, over which the tube sliding on its progress, the inside and outside are perfected together. A patent for a similar process had been granted in 1808, to a person of the name of Cook, for the manufacture of gun barrels: the schemes, at least, being identical so far as they each consisted in welding sheet iron or steel into tubes, and then perfecting them by passing them between grooved rollers.

Fig. 34.

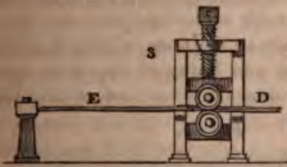
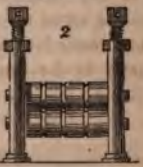


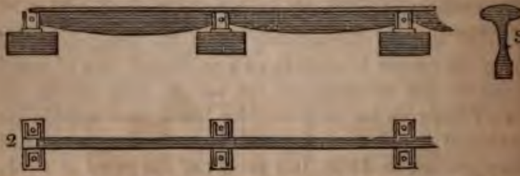
Fig. 33.



Iron Rails.

The introduction of malleable iron road rails for locomotive steam travelling and other carriage roads having created, as already observed, a new æra in the iron trade, the powerful and economical process of rolling has been introduced to facilitate the formation of this heavy description of articles, and has superseded to a large extent the use of cast-iron rails even of the most approved form and construction. Hammered iron rails of various forms were becoming general, when, in 1820, Mr. Birkinshaw, of the Bedlington ironworks, obtained a patent for an improvement in their form. The shape of the malleable iron rails previously used were bars from two to three feet long, and one to two inches square; but either the narrowness of the surface produced such injury to the wheels, or by increasing their breadth the expense became so great, as to make the cost greater than cast iron, which, consequently, was generally preferred. Mr. Wood, of Killingworth, in his Practical Treatise on Railroads, observes, that "it was to remedy these defects in the malleable form, and at the same time to secure the same strength as the cast iron, that Mr. Birkinshaw made his rails in the form of prisms, or similar in shape to the cast iron [ones of the most approved form]. 1, *fig.* 35. shows a side view of this kind of

Fig. 35.



rail; 2, a plan, and 3, a section of the same rail cut through the middle.

"These rails are formed by passing bars of iron, when red hot, through rollers with indentations or grooves in their peripheries corresponding to the intended shape of the rails; the rails thus formed present the same surface to the bearing of the wheels, and their depths being regulated according to the distance from the point of bearing, they also present the strongest form of section with the least material. The mode of rolling these bars or rails, and giving them the gradual swell towards the middle, not only in the horizontal section, but also a lateral swell commencing at each support, gradually increasing to the centre, and then again tapering towards the point of support, are very ingenious. They are generally formed in lengths of twelve to fifteen feet, and subdivided into bearing lengths of three feet each; but the patentee adds, in his specification: 'the respective rails may be made of considerable lengths (eighteen feet I should recommend), by which the inconvenience of numerous joints is reduced; and, consequently, the shocks or jolts to which the carriages are subject from passing over the joints (very much to the injury of the machinery) are also diminished. And in order still further to remedy the evil arising from the joints of the railroad, I propose to weld the ends of the bars together as they are laid down, so as to form a considerable length of iron rail in one piece.'

"The joinings of these rails, as shown in *fig.* 2. preceding, are square at the ends, similar to the old rails; but I see no difficulty in forming them with a half-lap, and thus giving them the same superiority of joining as possessed by the improved cast-iron rails."

Fig. 36.

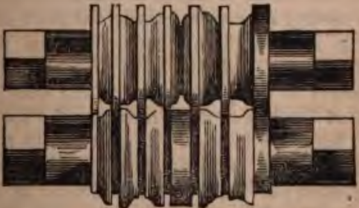


Fig. 36., given above, represents the rollers, as delineated in the margin of Birkinshaw's specification in the patent office. The open spaces along the middle of the figure, and which owe their figure to the moulding on the periphery of the rollers, indicate the form assumed by the iron rail as it is passed successively from the larger to the smaller apertures, till it is finished at the last.

An objection having been made to these malleable rails, on the ground that the great weight on the wheels rolling upon them expanded their upper surface, causing it at length to separate in thin laminæ, although the injury from direct oxidation was comparatively small, Mr. Longridge, one of the proprietors of the Bedlington works, proved that malleable iron rails, which had been laid down sixteen years at Tindale Fell, had no appearance of lamination; the whole of the weight of iron being indeed very little the worse for wear.

In a report on this subject by Mr. Stephenson, of Newcastle, the patentee of the cast-iron improved rail, the writer states that "the great object in the construction of a railroad is, that the materials shall be such as to allow the greatest quantity of work to be done at the least possible expense, and that the materials also be of the most durable nature. In my opinion, Birkinshaw's patent wrought-iron rail possesses those advantages in a higher degree than any other. It is evident that such rails can at present be made cheaper than those that are cast, as the former require to be only half the weight of the latter, to afford the same security to the carriages passing over them; while the price of the one material is by no means double that of the other. Wrought-iron rails of the same expense admit of a greater variety in the performance of the work, and employment of the power upon them, as the speed of the carriages may be increased to a very high velocity without the risk of breaking the rails; their toughness rendering them less liable to fracture from an impulsive force or a sudden jerk. To have the same advantages in this respect, the cast-iron rails would require to be of enormous weight, increasing of course the original cost.

"From their construction, the malleable iron rails are much more easily kept in order. One bar is made long enough to extend over several blocks; hence here are fewer joints or joinings, and the blocks and pedestals assist in keeping each other in their proper places. On this account, also, the carriages will pass along such rails more smoothly than they can do on those that are of cast iron.

"The malleable iron rails are more constant and regular in their decay, by the contact and pressure of the wheel; but they will, on the whole, last longer than cast-iron rails. It has been said by some engineers that the wrought iron exfoliates, or separates in laminæ, on that part which is exposed to the pressure of the wheel. This I pointedly deny; as I have closely examined rails which have been in use for many years, with a heavy tonnage passing along them, and on no part are such exfoliations to be seen. Pressure alone will be more destructive to the cohesive texture of cast iron than to that of wrought iron. The true elasticity of cast iron is greater than that of malleable iron; *i.e.* the former can by a distending power be drawn through a greater space without permanent alteration in the form, but it admits of very little change of form without producing total fracture. Malleable iron, however, is susceptible of a very great change of form, without diminution of its cohesive power: the difference is yet more remarkable when the two substances are exposed to pressure; for a force which, in consequence of its crystalline texture, would crumble down the cast iron, would merely extend or flatten the other, and thus increase its power to resist the pressure. We may say, then, that the property of being extensible or malleable destroys the possibility of exfoliation as long as the substance remains unchanged by chemical agency. A remarkable difference as to uniformity of condition or texture in the two bodies produces a corresponding want of uniformity in the effects of the rubbing or friction of the wheel. All the particles of malleable iron, whether external or superficial, resist separation from the adjoining particles with nearly equal forces. Cast iron, however, as is the case with other bodies of similar formation, is both harder and tougher in the exterior part of a bar than it is in the interior.

This, doubtless, arises from the more rapid cooling of the exterior. The consequence is, that when the upper surface of a cast-iron rail is ground away by the friction of the wheel, the decay becomes very rapid.

"The effects of the atmosphere in the two cases are not so different as to be of much moment. On no malleable iron railway has oxidation or rusting taken place to any important extent. I am inclined to think that this effect is prevented, on the bearing of surfaces of much-used railways, by the pressure upon them. To account for their extraordinary freedom from rust, it is almost necessary to suppose that some diminution takes place in the chemical affinity of the iron for the oxygen or carbonic acid. The continual smoothness in which they are kept by the contact of the wheels has the usual effect of polish, in presenting to the destroying influence a smaller surface to act upon. The black oxide or crust, which always remains upon rolled iron, appears to act as a defence against the oxidising power of the atmosphere or water. This is the reason why the rail does not rust on its sides."

Perhaps the most conclusive and valuable testimony in favour of the malleable iron roads, and especially of the rolled rails from the Bedlington works, is to be derived from the simple fact of their first adoption, with the latest improvements in their manufacture, in the railroad between Liverpool and Manchester, which was commenced in June, 1826, and opened with a splendid success on the 15th of September, 1830. The average expense of the rails on this line is said to have been about 12*l.* 10*s.* per ton, — apparently a high price, as compared with the facilities of their manufacture, and the market price of iron at the time.

The opening of this road will ever be historically identified with the catastrophe which, in the very midst of the ceremony, deprived society of a very excellent man, the nation of a highly experienced senator, and commerce of its warmest and most successful advocate. This allusion will be readily understood to refer to the right honourable William Huskisson, esq., late member of parliament for Liverpool, who lost his life in consequence of being run over by a train of steam carriages on the day when this railroad was opened, amidst an immense assemblage of spectators.

The rapid extension of railroads over every part of the civilised world has led to numerous improvements in the manufacture of rails, a few of which must be noticed.

The weight of railroad bars varies according to section and length. There are some of 40 pounds per yard, and some of 80 pounds, almost every railway company employing bars of a different section. Besides flat rails, which are still in use, we have bridge rails employed, which have the form of a reversed U. These have sometimes parallel sides, or, as in dovetail rails, the sides are contracted. The ∩ rails are more easily manufactured than the I rails, the difficulty of filling the flanges not being so great as in the latter rail. The rollers for manufacturing such rails are at least 22 inches in diameter, and make about 70 revolutions in a minute. The sections of these rollers are such as to produce the required form of the rails. After a rail is finished at the rollers, it is carried to the saws to be cut square at the ends. These saws are circular, with coarse teeth, and are about three feet in diameter, made of sheet iron, or in some cases of steel. They move with great rapidity, making 1500 revolutions per minute, and cutting through a rail in a few seconds.

From the saws the rail is put upon the straightening-bench, which is constructed according as the rail is ∩ or I-shaped, and by this and with sledges on an anvil, they have all twist taken out of them. A prize medal was given to Mr. W. H. Barlow of Derby, by the council for awarding prizes in this department of the Great Exhibition. The rail of Mr. Barlow is made to form its own continuous bearing. In section the rail somewhat resembles an inverted V, with ends considerably turned outwards. This portion forms the surface by

Fig. 36 *a.*

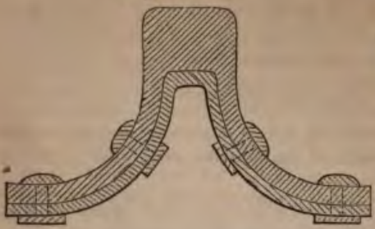
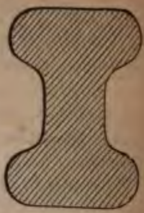


Fig. 36 *b.*



which the rail bears upon the ballasting, the apex of the Λ being formed with flanges in the ordinary form of rails, and the rail, therefore, beds throughout on the ballast. It can be very easily packed up and adjusted when out of place, and all the fittings of sleepers, chains, and keys are done away with, nothing being required besides the rails themselves, except a cross or tie rod at the joints, to hold them at the proper distance asunder, so as to keep the gauge of the line. These rails have been tried on the Midland line, and the result, as shown by the diminished oscillation and vibration of the trains in passing, and the smaller number of hands required to keep this portion of the line in order, are highly satisfactory. Many other lines have recently adopted this patent rail. *Figs.* 36 *a.* and 36 *b.* represent the patent rail and the old I rail.

A great importance has of late years been given to the manufacture of wrought-iron in large masses, by the increased scale which every form of construction in iron is assuming. At the Great Exhibition, the Derwent Iron Company exhibited a railway bar measuring 66 feet 9 inches in length.

CHAP. X.

BLACKSMITHS' WORK.

ANCIENT AND MODERN BLACKSMITHS. — SUBSTITUTIONS OF IRON FOR WOOD. — PLOUGHS, AXLETREES, AND WHEEL TIRE. — CELEBRATED BLACKSMITHS. — SINGLE, DOUBLE, AND CIRCULAR BELLOWS. — TEW-IRONS. — HORSE-SHOES, HOOFS, AND NAILS. PATENT SHOES. — MILITARY FORGES.

THAT important class of artificers in iron, anciently known in this country under the general and comprehensive designation of smiths, may be said to be represented by the blacksmith of modern times: the latter epithet itself has, indeed, been applied by some of our old writers in a much larger signification than that to which it is generally confined at present. It must, however, be remarked, that among our ancestors, and in modern trades more extensively, the appellation "smith" is suffixed to terms denominating the workers in various other metals as well as iron: — the goldsmith, the silversmith, the coppersmith, &c. being the well-known designations of men employed in manufacturing those metals. The smiths, however, noticed in our earliest records, and who were the first native iron workers, appear to have resembled, as to their avocations, the class of men mentioned in Scripture by the same term, not only in the general description of their tools and method of working, but even in their importance as armourers. "Now there was no smith found throughout all the land of Israel; for the Philistines said, Lest the Hebrews make them swords or spears: but all the Israelites went down to the Philistines, to sharpen every man his share, and his coulter, and his axe, and his mattock. Yet they had a file for the mattocks, and for the coulters, and for the forks, and to sharpen the goads."—1 Sam. xiii. 19—21. Apparently in reference to this very state of things, the Almighty is represented by the prophet as saying, "Be-hold, I have created the smith that bloweth the coals in the fire, and that bringeth forth an instrument for his work; and I have created the waster to destroy: no weapon that is formed against thee shall prosper."—Isaiah, liv. 16. It was on account of their importance in the fabrication of weapons, that workers of iron acquired their great distinction in the earliest periods of British power, and when the king's smith was honoured with the peculiar favour of the sovereign.

The modern blacksmith is distinguished from the whitesmith, or *brightsmith* as the latter has sometimes been called, by the circumstance of his finishing his articles upon the anvil, and in this state delivering them for use; or by smoking them over the fire, or smearing them while hot with pitch, and thus giving to them a glossy black and finished appearance. Neither the turning-lathe, the grindstone, nor even the file, are in general applied to perfect the productions of the blacksmith's handicraft. Besides the shoeing of horses, which is his chief and characteristic occupation, he is also the maker of common chains, plough and wheel tire, and, in fact, whatever of iron work attaches to the implements of husbandry generally; besides numerous other matters implied in the comprehensive designation of "jobsmith," which he mostly assumes.

The substitution of iron for wood has of late years taken place to such a large extent in articles connected with carriage and husbandry, that the demand for smiths' work, and, indeed, for the smith's ingenuity, has much increased. Not only the ploughshare and the coulter, and the teeth of the harrow, but ploughs and harrows, are entirely fabricated of iron, and, for both, patents have been obtained. Iron ploughs, although somewhat heavier than wooden ones, are allowed to work very easily, and last long; they are, however, much more used in Scotland than in England. In the little town of Alnwick, Northumberland, there is a somewhat noted maker of iron ploughs. In every plough, not only the parts above named, but the sole or under plate, and the curved side or slipe, formerly called the earth-board, from its turning over the sward or the soil when cut by the share and the coulter, are of iron or cast metal.

Iron axles for common carts have latterly come into great vogue, even with the poorer sort of people, as being both cheaper to uphold and easier to work than the thick wooden ones merely clouted with iron plates. An opposite opinion to this formerly prevailed: iron axles were allowed to work more smoothly in a nicely fitted metal nave bush; but, on account of the comparatively small diameter of the spindle part, and the inflexibility of the material, there existed a notion that a two-wheeled vehicle with iron axles distressed the horse much more than one mounted on wooden axletrees, where more play was usually allowed to the wheels. The compiler of this volume, who has travelled regularly during a quarter of a century along a road exhibiting, perhaps, a greater number of one-horse carts laden with coals than any other turnpike in the country, has noticed a considerable increase of three varieties of alteration in the construction of these vehicles within the last few years. In the first place, iron axles are becoming almost as common as once they were rare; and these not in the rough, as from the blacksmith's forge, but in general most accurately turned and fitted to the bushes. In the second place, no small proportion of these iron axles are covered with brass boxes, fitted into the nave of the wheel and revolving with it. By means of this admirable contrivance, not only is almost every drop of the oil retained within so as to maintain a perfect lubricity upon the metal surfaces in contact, but at the same time every particle of dirt is excluded from without. The third noticeable peculiarity consists in the tiring, the breadth, and the inclination of the wheels: instead of being nailed upon the outer periphery of the felloes in short, separate pieces, it is generally an entire rim riveted but in one place, and thus both binding the parts of the wheel most firmly together, and not being liable to get loose or fly off. Wheels, considerably increased in breadth on their shod surface, to take advantage of a late enactment which reduces tolls in favour of such, are not uncommon; nor are others of like width, and perfectly cylindrical, by any means of rare occurrence. Wheels of this last description are undoubtedly the best for sparing the surface of the road; and still more so are springs interposed between the body and axle of vehicles of any kind: as this arrangement saves both the road and the horse, it is to be regretted that any fiscal regulations should exist to prevent its most extensive adoption. The custom of making all sorts of carriage wheels revolve at the same distance, is an absurdity so injurious to roads, good or bad, that one wonders how turnpike trusts put up with it. The tiring of wheels with iron, or some other metal, was a part of the occupation of the smith in very early times. Ancient monuments exist, upon which the tire and the nails on the wheels of war-machines are very distinctly sculptured; and it is remarkable that the lava-paved streets of Herculaneum discover deep ruts, worn, no doubt, by the friction of metal-bound wheels.

The degree, however, in which the blacksmith deviates from the more laborious formation of common articles out of common iron, by the ordinary processes of forging, welding, riveting, &c., depends, in a great measure, upon his situation, and the employment of the people in his neighbourhood. In large towns, where whitesmiths and other classes of artificers abound, the blacksmith is perhaps seldomer engaged in their more appropriate, and to him not unfrequently less lucrative avocations. Indeed, so unprofitable is this occasional transition from the forging of black to the finishing of bright articles regarded in the north, that there exists an apophthegm to the effect that "The smith that is a blacksmith and a whitesmith too, maun gae shoe the goslings." Notwithstanding, however, this significant hint to the maker of horse-shoes to keep close to one business, it is generally observed that the Scotch blacksmiths enter more largely into the manufacture of miscellaneous articles than their English fellows.

It is, however, in villages remote from the large towns that the blacksmith may be seen to assume not merely his real importance as a mechanic, but his relative consequence as a member of society, by presenting that *factotum* character, which not only indicates that he is an indispensable artificer in iron and even steel, but which has led to his figuring in poetry, romance, and even music; for who has not heard of the "Harmonious Blacksmith" of Handel, the "Wayland Smith" of sir Walter Scott, and the "Wat Tyler" of Robert Southey? Besides the appropriate business of farriery, including the doctoring as well as the shoeing of horses, the anomalous avocations of cowleech, dentist, parish clerk, precentor, and newsmonger in general, have been collateral distinctions of the village Vulcan ever since, and, indeed, long before Shakspeare's celebrated passage was written, in which Hubert is made to say, —

> "I saw a smith stand with his hammer, thus,
> The whilst his iron did on the anvil cool,
> With open mouth swallowing a tailor's news;
> Who, with his shears and measure in his hand,
> Standing on slippers (which his nimble haste
> Had falsely thrust upon contrary feet),
> Told of a many thousand warlike French,
> That were embatteled and rank'd in Kent."
>
> *King John.*

And it so happens, that at the very moment of transcribing this page, an anecdote of so singular a character, as connected with an individual of this fraternity, is travelling through the newspapers, as irresistibly to tempt its preservation in this place, as more likely to reflect honour upon the craft in the estimation of most persons than the most notable incident in the life of St. Dunstan himself. — "At the late electioneering canvass for the Lanark district of burghs, between Mr. Gillon and Mr. Monteith, a poor blacksmith in Peebles, of the name of Alexander Brodie, was waited upon by Mr. Monteith's party, and actually offered 1000 pounds for his vote; but this the honest man firmly declined, and, in spite of all entreaties to the contrary, went and voted gratis on the side which his conscience told him ought to be supported. So great was the admiration excited by this instance of integrity, that one of Mr. Gillon's most distinguished friends lately presented to Mr. Brodie a handsome silver snuff-box bearing the following inscription, which is alike creditable to the donor and receiver:— ‘To Alexander Brodie, blacksmith, member of the town council of Peebles, this box is presented, as a mark of respect and esteem for the unrivalled instance of sterling worth and incorruptible integrity exhibited by him during the recent canvass for the representation of that burgh, by one of Mr. Gillon's oldest and most attached friends, sir James Dalzell, bart., of Binns. Aug. 23. 1830.’"

This slight digression from the craft to the character of the blacksmith may be the more readily excused, even by the most choleric reader, when it is recollected that in our enlightened times, instead of the trite terms "blacksmith and jobsmith in general," the maker of horse-shoes paints on his sign-board "veterinary forge," at the least: and there is, or at least was a few years ago, over a common horse-shoeing blacksmith's shop adjoining the Eglise de St. Sulpice, at the end of the rue Feron in Paris, the words "*artiste vétérinaire!!!*"

The interior fitting and furniture of a blacksmith's shop is that of a smithy in general, comprising a hearth, bellows, vice, anvil with bick-iron, water-trough, &c.: his portable tools are few and simple, compared with the complex paraphernalia of the whitesmith. As his bellows are of special importance, it is requisite not only that they should be large enough, and properly constructed to produce a sufficient blast, but that they should be made of good materials, otherwise they will be continually getting out of order, and thus be productive of inconvenience and expense to no small amount. The usual form of the smith's bellows approaches that of a boy's kite, and they are either single or double: in the former case they consist simply of two well-seasoned elm boards of the shape just mentioned, along the sides and round the wide end of which a pliable piece of leather is fastened by means of flat-headed nails driven through it into the board at near intervals, and distended in folds circular end by light wooden hoops fixed inside. smaller extremity, the upper board on a hinge is d to a cog of wood, through which the metal pipe emission of the blast is also fastened: the lower which in these single bellows is stationary in an ntal position, has a hole with a valve or clack, opens upwards in the inside, and thus admits the en the superior board rises, and closes again to of its being expelled through the pipe when that falls, which it is generally made to do with suf- force by means of a weight placed upon it. Bel- this kind resemble, in fact, those commonly used hens, and which, as they only emit a blast during of compression, or, in other words, while the board is falling, the blowing is merely a succession rrupted puffs: to overcome this inconvenience, and e a continued blast, two pairs of these single bel- re placed alongside of each other, the boards of are alternately raised and suffered to fall by means eciprocating motion of a lever to which the rocker lstaff is attached. In general, however, the smiths dopted the very superior double bellows, in ap- e about twice as deep as the others; they consist tionary board in the middle, with a moveable one nd below, being, in fact, two bellows working on erior and superior sides of a common fixed plane: e there is a valve in the middle as well as in the board; and as the nozzle or pipe of the bellows mmunicates with the upper chamber, it will be that when the inflation is kept up, there must be passing through the pipe a regular current of r when both lobes are distended, if the under- e drawn upwards by depressing the staff, the air d through the valve in the middle board and out vent; when, on the other hand, by raising the he lower board is suffered to fall, the weighted ne following it, forces the enclosed air against uts the inner valve, so that the current is com- o issue at the proper orifice. Thus, by alternately raising and depressing the lower board, by which means the upper one is raised and depressed at the same time, an uniform and constant blast is maintained.

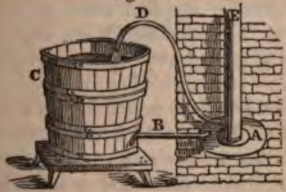
In the construction of bellows, the leather should not only be sufficiently pliable to work easily, and strong enough not to wear out presently, but likewise of such a texture that it shall not allow the air to escape through its substance. Well dressed ox or cow leather is generally preferred, and, when in use, is occasionally dubbed over with neat's oil, or some other unctuous substance, to prevent it from cracking, and to render it more entirely impermeable to the air. Virgil, who incidentally recommends bull leather as proper for this purpose, would certainly obtain but little credit for sound judgment on this subject among modern bellows-makers. All the materials being good, the strength of blast which a pair of bellows can produce depends upon the quantity of air received, and the force with which it can be expelled; the former, of course, varies according to the area of the boards and the extensibility of the leather; the latter according to the length and leverage of the handstaff, and also of the bellows-boards.

Some years ago, a patent was obtained by a clever bellows-maker of the name of Lindley, for circular bellows; which, as they occupy but half the room of those of the ordinary construction, and, in consequence of their vertical motion, inhale a larger volume of air, they have obtained considerably, especially when not required of a very large size; for as they have no board leverage, like the oblong-shaped bellows, they cannot be worked with the same ease as the latter.

The Chinese smiths have bellows of a very simple construction, being composed of a square pipe of wood, within which works a square piece of wood in the manner of a piston, and which is made to fit sufficiently tight without leathering: at the bottom of the box is the pipe, with a valve opening inwards. Wooden bellows, or blowing boxes, have long been in use among the continental nations, especially in Germany. Samuel Reyher, an author quoted by Beckmann, says, in a work published in 1725,—"About eighty years ago, a new kind of bellows, which ought rather to be called the pneumatic chests, was invented in the village of Schmalebuche, in the principality of Cobourg, in Franconia. Two brothers, millers, in that village, Martin and Nicholas Schelhorn, by means of some box made by them, the lid of which fitted very exactly, found out these chests, as I was told by one of their friends, a man worthy of credit. These chests are not of leather, but entirely of wood, joined together with iron nails. In blacksmiths' shops they are preferred to those constructed with leather, because they emit a stronger blast, as leather suffers the more subtle part of the air to escape through its pores."

In order to prevent the iron passage-pipe of the bellows from being burnt away, by lying constantly in contact with the very hottest part of the fire, it is usually placed in a stout perforated core of cast or wrought iron, called the tewel or tew-iron. This is either simply a perforated clod of metal, lying between the nose of the bellows-pipe and the fire; or it is a more ingenious contrivance, denominated a *water tew-iron*, the construction of which will be readily comprehended by referring to *fig.* 37. A is the wide and outer end of the tew-iron, as it appears when inserted through the wall of the furnace. It consists of two cones of iron, one within the other, welded together at the point, and at the end exposed to view in the cut, and by this forming a chamber or space between them. Communicating with this cavity are two iron pipes, screwed into holes bored through the front

Fig. 37.



of the tew-iron: the lower pipe B is placed horizontally, and communicates with the water tub C. Through this pipe the water flows into the chamber of the tew-iron, and prevents it from burning away so rapidly as otherwise it would by exposure to the fire. In order to provide for the emission of vapour, and a portion of the water which is kept in such a high state of ebullition, there is the other pipe D, which being inserted through the upper part of the tew-iron, and bent so that its superior orifice falls over the tub, a perpetual issue of hot water and steam takes place during the operation of the bellows, while a constant supply of cooler water is forced in, by the weight of that which is in the tub forcing it through the horizontal pipe B. In some smithies the bellows are placed up aloft, to be out of the way; in which case they are worked by means of a rope attached to the lever, and the blast is communicated through a descending pipe, as indicated by E.

The practice of affixing plates or pieces of metal to the feet of horses, in which the blacksmith's business chiefly consists, is generally allowed to be of great antiquity; though at what period it was first introduced appears by no means certain. Ancient classic writers frequently mention the defences of horses' feet, in terms similar to those used when they speak of shoes in general; they likewise mention them as being of metal. We are told by Suetonius that Nero, when he took short journeys, was always drawn by mules which had silver shoes: and those of his wife Poppæa, according to Pliny, had shoes of gold. There is nothing, however, deducible from the Roman writers, which can fairly authorise the belief, that in the former case any thing more is meant than mere chirurgical bandages, or socks of some kind; nor in the latter, that the shoes of precious metal were any thing else than thin slips, attached over the hoof by way of ornament, and removeable at pleasure: at all events, there is no ground to suppose that they were connected with soles permanently fastened with nails to the corneous substance of the foot, according to the method of modern times. The figures on ancient monuments afford still feebler evidence of the very early origin which some authors have claimed for the art of nailing metal shoes upon the feet of horses.

According to Beckmann, the Greek word σελιναια, which, he is convinced, signifies horse-shoes such as are used at present, occurs for the first time in the ninth century, in the works of the emperor Leo; and this antiquity of horse-shoes, he adds, is in some measure confirmed by their being mentioned in the works of Italian, English, and French writers of the same century. The word occurs, in the tenth century, in the *Tactica* of the emperor Constantine, where he says, that a certain number of pounds of iron should be given out from the imperial stores to make *selenaia*, and other horse furniture. Eustathius, who wrote in the twelfth century, uses the same term in the same sense as that in which it is here interpreted. "When one considers," says Beckmann, "that the σελιναια, or σεληναια, belonged to horse furniture; that they were made of iron; that, as Eustathius says, they were placed under the hoofs of the horses; that the word seems to shew its derivation from the moon-like form of shoes, such as those used at present; and lastly, that nails were necessary to these *selenaia*; I think we may venture to conclude, without any fear of erring, that this word was employed to signify horse-shoes of the same kind as ours; and that they were known, if not earlier, at least in the ninth century."

The same author mentions, that when the marquis of Tuscany, one of the richest princes of his time, went to meet Beatrix his bride, mother of the well-known Matilda, about the year 1038, his whole train were so magnificently decorated, that his horses were shod not with iron, but with silver. The nails even were of the same metal; and when any of them dropped out, they belonged to those who found them. The marquis appears to have imitated Nero: but this account, which is in verse, may be only a fiction. It is well known, however, that an ambassador from this country to the court of France indulged in a similar folly, to exhibit his opulence and generosity; having had his horse shod with silver shoes so slightly attached, that, by purposely curvetting the animal, they were shaken off, and allowed to be picked up by the populace!

The following passage on this subject is likewise from Beckmann: "Daniel the historian seems to give us to understand that, in the ninth century, horses were not shod always, but only in the time of frost, and on other particular occasions. The practice of shoeing appears to have been introduced into England by William the Conqueror. We are informed that this sovereign gave the city of Northampton, as a fief, to a certain person, in consideration of his paying a stated sum yearly for the shoeing of horses; and it is believed that Henry de Ferrers, who came over with William, and whose descendants still bear in their arms six horseshoes, received that surname because he was entrusted with the inspection of the farriers;"—*ferrière* (from *ferrum*, iron) signifying, in French, a bag of instruments used in the shoeing of horses. That the practice of shoeing horses in this country may have become more common after the conquest may easily be conceived; and it is certain that a number of smiths came over with the Norman army: but that the thing was not new at the time is clear, from the historical fact, that Welbeck, in Nottinghamshire, the very estate on which, at this day, stand the capacious stables formerly belonging to that famous writer on horsemanship, the duke of Newcastle, was, before the conquest, the property of an old Saxon tenant *in capite*, named Gamelbere, who, according to Dugdale, held of the king two *carucates* of land, by the service of shoeing the king's palfrey on all four feet, with the king's nails, as oft as the king should lie at his manor of Mansfield; and if he should lame the palfrey, then he should give the king another palfrey of four marks price.

Among the various subjects treated upon in the multivarious works published during the revival of literature in the fifteenth and sixteenth centuries, the art of shoeing horses was not neglected, especially by Italian, French, and German writers. And subsequently, in this country, the subject has been taken up, either as a separate branch, or as a part of the general science of farriery, by a multitude of writers, good, bad, and indifferent; the mere catalogue of whose names would furnish no gratification, and whose works it would be out of place to particularise at present. William Osmer, a surgeon; the earl of Pembroke, who wrote an excellent treatise on practical horse-shoeing; Clarke, formerly the king's farrier for Scotland, who treated in a useful manner the same subject; and, lastly, Mr. Coleman, of the Veterinary College, who has effected important innovations upon former methods of shoeing, may be mentioned as names most familiar with those shoeing smiths who superadd the smallest acquaintance with the anatomical formation of the horse's foot, and the fittest method of protecting it scientifically, to the mere duty of nailing upon the hoof of a valuable horse a clot of iron to defend it from injury, with as little judgment as they sometimes nail a similar one behind their dwelling-house door, "to keep the witch out!"

As the foot of the horse in a state of nature must always have been pretty nearly of an uniform shape; so the form of its shoe, since its first application, may be supposed to have deviated but little in its general outline from that in use at this day, although in its absolute fashion many alterations and improvements have taken place.

In order to enable the reader more clearly to understand those differences between former and latter practice in the art of shoeing afterwards noticed, it may be convenient briefly to enumerate the parts of which the horse's foot is externally composed. The whole of the hoof consists of horny fibres, without the smallest degree of sensation. The crust or wall surrounds the anterior and lateral parts of the foot: to this crust the shoe is fastened, as it is the only part that can receive nails without mischief. It is smooth and convex on the outside, but laminated and concave within, for the purpose of being united with corresponding laminæ covering the lowest bone of the foot, called the coffin-bone: this union of the crust with the coffin-bone sustains the whole weight of the animal. United with the lower part of the crust, and covering the inferior surface of the coffin-bone, is the horny sole, concave on the outside, and within adhering to and protecting a sensible vascular substance called the feeling sole. In the centre of the sole is placed the frusk or frog, an insensible body, externally convex, of a wedge-like form, pointed towards the toe, but expanding where it approaches the heels. Two horny bars or binders are placed between the frog and the sole, and at the heels form a broad solid junction with the crust.

According to Mr. Coleman, the toe of the sensible and horny frogs, from their connection with the coffin-bone, are fixed points, and have no motion; but the heels of the frogs being placed posterior to the coffin-bone, and in contact with moveable elastic substances, a very considerable lever is formed; and whenever the hoof comes in contact with the ground, the frog first ascends and then descends. The ascent of the frog expands the cartilages, preserves the heels from contraction, and affords to the horse an elastic spring, while its wedge-like form prevents the animal from slipping whenever it embraces the ground.

According to long established opinion, the frog has generally been regarded merely as a cushion to the superincumbent parts, or to guard the flexor muscle of the foot: under this universal impression a thick or high-heeled shoe was regarded as indispensable, in order to protect the tendon from injury. It is, however, the principal object of Mr. Coleman, in an elaborate treatise, to prove, from the shape and situation of the frog, that it was formed *to come in contact with the ground*, and, consequently, that a system of shoeing very different from that commonly practised ought to be adopted.

Instead, therefore, of cutting away the bars entirely, paring down the frog, and applying a convex shoe, thicker at the heel than the toe, and extending almost round the crust, according to the old system, Mr. Coleman reverses the practice almost entirely: he leaves the bars to their natural duty of expanding the heels; allows the frog to come into direct and continual contact with the ground; applies a *shoe nearly flat*, exceedingly light and small, and two thirds thicker at the toe than at the heels. The reason for reducing the size of the shoe so materially from a large to a small portion of a circle is, that its extremities may not rest upon the seat of the corns to which horses are liable, and the situation of which is between the bars and the crust. As to the quantity of metal which should be used, Mr. Coleman proposes that the shoe and nails of a common sized coach horse should weigh about eighteen ounces; the web being one inch wide at the toe; three fourths of an inch at the heel; three sixths of an inch thick on the outside of the toe, and one inch on the inside; the heels one third the thickness of the toe: and the shoe and nails of a saddle horse about twelve ounces; width at the toe six eighths of an inch; one fourth less at the heels; three eighths of an inch thick on the outside at the toe; inside of the toe and heel one eighth. The shoe should remain on the hoof about twenty-eight days.

The use of eight nails in fastening the shoe to the crust of the hoof is of long standing among farriers, nor does Mr. Coleman recommend more or fewer; but only that, instead of being distributed four on each side, and, consequently, some of them very backward, he advises that they should be carried all round the toe, and be kept as far from the heels as may be compatible with security to the shoe, especially in the inside quarter. A manifest improvement has taken place in the form of the nails, and the corresponding perforations in the web of the shoe. Formerly they were all, as in too many places they are still generally made, with square heads, as represented in *fig.* 38., the shoes being fullered or grooved near the outer edge to receive the heads, and protect them as much as possible from being knocked or worn away. A better practice, however, has introduced the nail with a wedge-shaped head, *fig.* 39.; and instead of the fullering, the holes are correspondingly fashioned with a steel punch; so that when the nail heads are driven up until level with the surface of the shoe, the whole presents the appearance of one solid piece. In most shoeing forges, the practice of countersinking the holes, to receive the nail heads, obtains to a greater or less extent, even when the shoes are channelled along the margin; a custom which the country smiths do not appear disposed to lay aside.

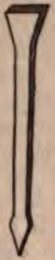


Fig. 39.

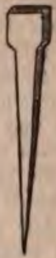


Fig. 38.

Many of the country blacksmiths make their own nails; but this is neither an economical nor a desirable thing where many are used, as the nailors in general furnish them both better and cheaper than the smiths can make them. The horse-shoe nails approved and used at the Royal Veterinary College, and which are certainly much superior to those in common use, are thus noticed by Mr. Coleman, in his "Observations on the Foot of the Horse, and the Principles and Practice of Shoeing:"—"This kind of nail is the invention of Mr. Spencer, a very ingenious horse-nail maker; and although the quality of the iron, and the form of the nail, render this article infinitely superior, not only in shape but durability, yet the price is not more than sevenpence per thousand more than the common nails. And, from the experience I have had of their utility, I am persuaded that the shoes are not only more securely attached to the hoof, but that the smith will find it very economical to use them universally in his practice. But if the increase of expense were an object of consideration, it is of much more consequence not to lose a shoe, and particularly in hunting. The head of the common nail is not conical, but nearly square; and no part is received into the nail-hole. When the nail is driven into the shoe up to the head, the farrier generally continues to hammer with great violence; and as the nail-hole cannot admit the head, the texture of the nail contiguous to the head is shivered, and in a few days is broken: whereas the head of Mr. Spencer's nail operates as a wedge; the more it is hammered, the more firmly it is connected with the nail-hole, so as to become part of the shoe."

In shoeing horses, three particulars should be especially attended to, — the material of the shoe, its form or adaptation, and the mode of fastening it to the foot. The first item in the old formula, "Take the best Spanish iron," is too little attended to by many of our smiths, who content themselves and their customers by using common English iron, which is sadly too soft and perishable for the purpose. In the better sort of forges, however, the best British iron is generally used; the rods for this purpose being from three quarters of an inch to one inch and a quarter broad, and half an inch thick: two men are employed at the anvil, a maker and a striker, who, together, will turn two or three dozen of ordinary shoes in a day. These are either light flat disks, as they are for saddle horses, &c., or of much greater strength, with welts or knobs on the toes, and bent down as much as an inch at the heels when for heavy draught horses, in order that the feet may the better impinge upon the road when the animal is drawing a vehicle. The former class of shoes weigh about twelve ounces; while many of the latter are as much as five, six, and in some instances even seven pounds' weight. And yet this weight of metal is so rapidly abraded or worn away as to require the being replaced by a new shoe generally about once a month; and in some cases, a horse, whose foot has an awkward twisting or grinding motion on the ground, will wear out a shoe in three or four days; indeed, the diversities of manner in which different horses, and the same horses with different feet, act in their contact with the road, are considerable, and require to be especially attended to by the farrier. Some horses' feet, from their stabbing walk, have a tendency to drive the shoe backward, and thus to loosen it by drawing the nails: to provide against this, it is usual to make what is called a clip on the toe, which is the iron turned up a little to allow the hoof to abut against it. For the use of some horses, which have a sort of screwing motion with their feet, these clips are likewise raised on each side; by this means the wrest upon the nails is much diminished, and the shoe rendered more firm and useful. Eight nail-holes are then pierced near the outer margin of the web of the shoe, and a channel cut, in which the heads of the nails are buried, more or less, according to its depth or the formation of the holes.

Besides the common shoes, there are a variety of shapes, made to be used when the hoof is irregular, or for particular occasions: the principal of these are the circular shoe, to extend all round the foot, when it is necessary to defend the heels: the bar shoe, which is used when the bars of the hoof have been too much pared away, or when it cannot bear much lateral stress. When a horse's hoof is imperfect on one side, a calkin or welt on the shoe is added; and in some cases, when the tread is very uneven, a bit of steel is welded upon the shoe where it wears out fastest. On turning horses out to grass, it is common to remove their heavy shoes, and furnish them with light ones, or tips as they are called, extending only a little beyond the toe on each side. These tips are made in various shapes, according to the judgment, the fancy, or the prejudice of the farrier, or the owner of the horse: generally, they have a tongue of some kind, to protect the frog of the foot; and some have even been made with a joint or hinge at the toe, to allow of any expansion or growth of the hoof which it might be anticipated would take place. Hunters are sometimes shod with cast-iron shoes, about half an inch thick on the outer edge, but lightened by means of a deep concavity running in the direction of the curve of the shoes, and terminating with a thin beaded margin within: the object is, that the horses' feet may not slip, but take firm hold of yielding ground. However simple this branch of the blacksmith's business may appear, it has not been found possible to supersede the ordinary use of the hammer by any useful machinery; though this has been tried. Many years ago, a veterinary surgeon of the name of Moorcroft obtained a patent for facilitating the manufacture of horseshoes by the application of rollers. His project was to cut in the periphery of the rollers, grooves to suit the size of the iron proper for a shoe, and in these grooves to leave a prominent line and projecting points, which should impress the metal with the channel and nail-head cavities usually communicated by the hammer. The bars of iron so rolled were then to be cut into proper lengths, and turned into shape on the beak of the anvil as usual. The same projector likewise included in his scheme the practicability of forming horseshoes by stamping them into shape at once by means of dies appropriately cut for the purpose. The dies for this purpose were to be "formed in such a manner as to correspond with those parts of a horse's foot to which shoes are usually affixed;" when, therefore, the diversity of formation to which the hoof is liable, and the expense of cutting dies, are considered, it can be no wonder that so impracticable a scheme should have been almost forgotten.

It may likewise be mentioned, that various contrivances for fitting to the feet of horses shoes made of felt, between the hoof and the metal, have at different times been had recourse to. In 1816, a gentleman of the name of Rotch procured a patent for what he designated a "flexible elastic horse-shoe." This flexible shoe is so formed, that when it is applied to the foot of the horse, it accommodates itself to the motion occasioned by the natural elasticity of the different parts of the foot, thereby allowing the natural expansion of the heel, and at the same time protecting the hoof from injury on the road. The flexible horse-shoe consists of two or more pieces of iron, steel, or other metal, attached either by the nails which fasten the shoes to the foot, or by rivets expressly for the purpose, fastened to leather, felt, Indian rubber, or other flexible substance; which substance, on applying the shoe to the foot, is interposed between the horn and the iron. The most simple method of making the flexible horse-shoe is by cutting a piece of stout sole leather to the size of the horse's foot, and which may be in other respects formed like a common horse-shoe, the web being somewhat wider than usual. Then forge an iron shoe in the ordinary way, and divide it into three parts by cutting it across at those parts of the quarters to where the points of the coffin-bone would extend; and rivet the three pieces so made on the before-mentioned piece of leather. The shoe thus made is applied with nails in the ordinary manner.

Men, even learned men, are liable to strange extremes: while some are for loading the feet of horses with several pounds' weight of iron each, others have been for abandoning the use of shoes altogether. Of this opinion was William Osmer, a surgeon, who wrote a book on farriery, which has been of great use in practical horse-shoeing: it abounds, however, in whimsicalities; as a specimen of which may be taken the following passage, introductory to the chapter "proving that shoeing is but a partial good:"—"When time was young, when the earth was in a state of nature, and turnpike roads as yet were not, the horse needed not the assistance of the artist; for the Divine Artist had taken care to give his feet such defence as it pleased him; and who is weak enough to suppose this wisdom was not sufficient to the purpose in such a state?" The arguments which follow this specious exordium have drawn upon their author the censure of Taplin, a subsequent writer of note on farriery, who observes, that Osmer, and those of his opinion, "appear extravagantly fond of an idea borrowed from antiquity, upon the practicability of horses travelling the road, and doing their constant work, without any shoeing at all;" and to the remark, that "horses are adequate to their different services in a state of nature without the officious obtrusions of art," Mr. Taplin replies, that "such economical plan may be admirably calculated for the theoretical journey of some literary speculatist," but affirms that "no other excursion can take place of any duration without material injury to the hoof, unless in the case of the high-bred horses of authors, who enjoy their journeys only in imagination."

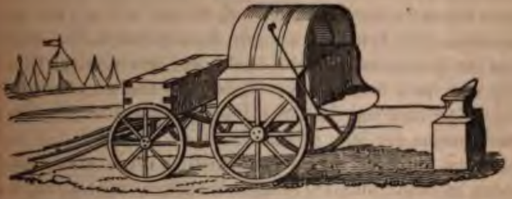
Before the invention of metal shoes, considerable attention, as may well be supposed, was paid to the strengthening and hardening the hoofs of horses, especially of those employed in war; and various whimsical methods of producing these effects are still extant in the works of those who have treated on the ancient ménage. Notwithstanding, however, that attention, sharpened as it must have been by the value of the animals upon whom it was bestowed, there is but too good reason to believe, from incidental passages in the writers of early times, that dreadful havoc must frequently have taken place amongst, and still more dreadful sufferings have been endured by, those noble animals, of whose preservation, even in military service, so much care is taken in modern times, and to which preservation the art of shoeing especially conduces.

That the horses of the ancients were never shod in war, is the opinion of Beckmann; nor does it appear that conclusive evidence to the contrary has been adduced. When Mithridates was besieging Cyzicus, he was obliged to send his cavalry to Bithynia, because the hoofs of the horses were entirely spoiled and worn out. In the Latin translation of Appian, where the sentiment occurs, it is added, that this was occasioned by the horses not having shoes; but there are no such words in the original, which seems rather to afford a strong proof that in the army of Mithridates there was nothing of the kind. The case seems to have been the same in the army of Alexander; for we are told by Diodorus Siculus, that with uninterrupted marching the hoofs of the horses were totally broken and destroyed. An instance of a like kind is to be found in Cinnamus, where the cavalry were obliged to be left behind, as they had suffered considerably in the hoofs; "an evil," says the historian, "to which horses are often liable."

In the military service of this country, the right shoeing of the horses in mounted regiments is a matter of considerable importance. In each troop of dragoons there is a farrier, who was formerly under a person called the farrier-major, appointed by the colonel. This officer has of late years been superseded by a veterinary surgeon, under whose immediate control and superintendence troop farriers act in all that relates to the health and the management of the horses. All the horses' shoes are to be made according to the regimental pattern; and when the farrier goes round, after riding out, or exercise on horseback, it is his duty to carry with him his hammer, pincers, and some nails, to fasten any shoe that may be loose. In some corps it is a standing regimental rule, that if the farrier in any manner lame a horse, he must be at all the expense in curing it. In barracks there is always a smithy, where the horses are shod, and any other necessary jobs done; but in a train of artiller there is what is called a travelling forge, and which is in fact, a sort of portable blacksmith's shop. At thi forge all manner of smiths' work is executed, and it can be used upon a march as well as in camp. Formerly these forges were very ill contrived, having two wheels only, and requiring to be propped with wooden supporters when used for working in the park. Of late years they have been made with four wheels, which is a great improvement.

One of these travelling military forges is represented in *fig.* 40.: it consists, properly speaking, of two bodies, each mounted upon two wheels, and connected by means of a pole, somewhat like that of a chaise, passing from the hinder carriage transversely over the axletree of the former, thus uniting both together. Upon this pole, between the two bodies, the anvil and its stock, which are separable, are generally placed during the removal of the vehicle. The fore-wheels support a stout oblong coffer, bound with clamps of iron, and containing as well a quantity of coal as the smith's tools in general. The other body is a sort of tilted cart, the bellows occupying the inside, and being worked by a rockstaff from without: behind is the fireplace or hearth, consisting of an upright cast-iron plate with cheeks, and an horizontal bottom, slightly hollowed to retain the fire, and projecting to some distance from the vehicle behind. On either side of this latter body, between the bellows and the wheels, are attached boxes for the reception of iron and implements.

Fig. 40.



In 1819, a patent was granted to a person of the name of Cherry, a veterinary surgeon of Croydon, for a portable frame-forge: it consisted of a pretty large frame, readily disjointed, which, with the anvil, stock, bellows, and other necessary implements of a blacksmith's shop, could be packed up in a box of no great dimensions. It was particularly recommended to the notice of shipowners, as being more convenient than any of the forges before in use. A smith's forge of this or some other construction is, especially in long voyages, almost a necessary article of naval equipment: but those commonly in use, being mostly in detached parts, are very liable to be mislaid or lost, whereby the forge may be rendered incomplete, and, perhaps, useless when most wanted, besides being much more heavy and bulky than Mr. Cherry's forge, which, when not set up for use, occupies but little more room than a seaman's chest, is perfectly complete within itself, and may either be set up and used on deck, or landed for the purpose. Its adoption into vessels not usually supplied with a forge was recommended, as calculated to save expense, and prevent much of that delay which is often experienced both at home and in foreign harbours, by waiting the convenience of a native blacksmith at a distant forge.

CHAP. XI.

CHAINS.

VARIOUS DESCRIPTIONS OF CHAINS.—METHOD OF WELDING IRON LINKS.—KNOTTED TRACE CHAINS.—PIT CHAINS.—HAWKS, BRUNTON, BROWN, AND ACRAMAN'S CHAIN CABLES.—ADVANTAGES OF CHAIN CABLES.—SOWERBY AND GLADSTONE'S CHAINS.—COMPARATIVE ESTIMATE OF CHAINS AND ROPES.

THE art of making chains, not only of the precious metals for ornamental, but of iron for useful purposes, may lay claim to considerable antiquity. They are mentioned frequently both in the Old and New Testament, in some instances when used, as was often the case, by way of ornament, and in others as instruments of confinement or degradation. For the latter use they were common among the Romans, who, when they went to war, generally carried with them chains for the fastening of their prisoners, as well of high as of low degree. Of this practice, and the degrading circumstances sometimes accompanying it, history affords many examples. The chains used for purposes of this kind were generally of iron, but sometimes they were of silver and even of gold. Catenæ, or linked rings of the precious metals, or gold and silver wire, looped in some manner so as to be flexible for the purpose of being worn as ornaments by official or dignified personages, undoubtedly led to the manufacture of stronger chains of the inferior metals for useful and other purposes. Hence the art of making the former description of chains, by exceedingly simple means, and with few tools, is practised in countries where the knowledge of welding iron is probably hardly known to the artificer.

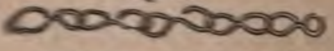
Whether or not this act of working the precious metals was known to the aborigines of this island, does

[illegible] it has, apparently with a view of c
[illegible] of Tacitus, that Britain produ
[illegible] been maintained that a great numbe
[illegible] of native manufacture were taken fro
[illegible] Caractacus, and sent in a sort of t

[illegible] what period, or under what circumstance
[illegible] of the common kinds of useful ch
[illegible] in this country, we cannot accurately
[illegible] have long been renowned
[illegible] of curious chains, or strings
[illegible] which watches, tweezer cases, and t
[illegible] used to be suspended. These art
[illegible] imitated by foreigners as the Eng
[illegible] and in various countries, an e
[illegible] textures, made of different kin
[illegible] made their appearance, th
[illegible] description of which would be almo
[illegible] general an amateur attempt to i
[illegible] would be unsuccessful.

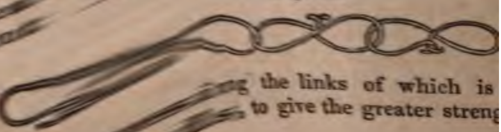
Perhaps [illegible] one of the simplest and almost th
forms of chain is that, the links of which are
by bendin[g] a bit of wire into a sort of loop a
and bendin[g] the other end in like manner, onl
loops make right angles with one another, *fig.* 4

Fig. 41.



the brass c[illegible] usually connected with the sm
in retail shop[illegible] Made stronger, and of iron, it
weighing he[illegible] articles, and as a dog-chain.
very differen[illegible] another well known chain

Fig. 42.



the wire comp[illegible] the links of which is
twisted at the [illegible] to give the greater streng

however, both less neat and less strong than the links *fig.* 43., which are made of coils of wire, drawn together in the middle, and then wrapped about with the wire. *Fig.* 44. and *fig.* 45. are chains made of wire: they are both of considerable antiquity.

Fig. 43.

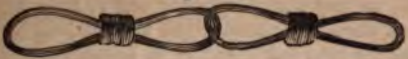


Fig. 44.

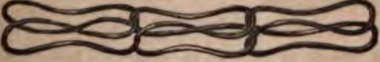
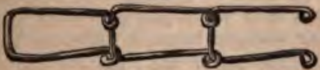


Fig. 45.



In the manufacture of chains for almost all the ordinary purposes to which they are now applied, the links are either pieces of wire simply bent into the desired form, and the ends of the material brought into such contact with the shank or with each other, that they maintain their connection; or they are soldered together; or, lastly, they are welded in the usual manner of uniting pieces of iron. This is the common process in nearly all the varieties of iron chain at present in use, where any considerable degree of stress has to be endured.

Instead of forging the material for the link out of a light bar of square iron, as was the practice formerly, the general course is to use round iron, which is reduced exactly to the size required by being passed through grooved rollers. The workman takes a rod of this iron, heats it in his hearth to a cherry red, and then withdrawing it, he places it upon a chisel, and measuring the length requisite to form a link, gives it a stroke with his hammer, and bends it into the shape of a U. Then taking hold of this half-formed link with his tongs, he inserts it again in the fire; and having brought both points to a welding heat, he unites them by hammering on the beak or point of his anvil, taking up, of course, as he proceeds, in every case the link last formed, which, for the convenience of catching easily, he hangs upon the beak above mentioned, while he heats and bends the iron for the next link; and so in succession with each, until his chain be of the length required. The dexterity with which a clever workman performs this process of linking common light chains can only be conceived of aright by those who have either witnessed this or some similar manufacture.

The most common form of the link in chains for ordinary purposes is that of an oval, the stress being, of course, always in the direction of its longer axis; this form, however, is varied according to circumstances, and as lightness or strength becomes indispensable. In the former case, as for traces, the links are generally made considerably oblong; whereas, in crane and similar chains, the ovate form is contracted in length as much as is compatible with the free motion of the links in each other. It must be obvious that in common chains, which are continually in use, the principal wear will be on the inner surface of the extremities, where the links are in contact, and with considerable motion when the chain is in use; and hence it was no uncommon thing to see cart traces worn quite through at the ends, while the sides were nearly as stout as when first made. To remedy this evil a very simple alteration was made; the link, instead of being of uniform substance, as heretofore, was made thicker at the extremity of the oval, and thus the durability of the chain was indefinitely increased. As, however, this method added much to the labour and consequent expense of the article so made, when wrought by the hammer in the ordinary manner, Mr. Hawks, a metropolitan iron-master, who introduced this improvement, obtained a patent for manufacturing chains of this description out of iron drawn into the proper form by being passed through rollers, the grooves in which were deeper and shallower, at distances answering to the circumference of a link; so that the maker had merely, as in the case of round rods, to cut off and weld the links in the usual manner. These *knotted* chains, as they are called, are now made by all the chain-makers.

The heaviest traces, and they are generally of the make just described, — are those used with the London dray-horses; the next sort by the Suffolk and Norfolk farmers, for plough traces; and a still lighter kind, called the Edinburgh traces, are used by the Scotch. The Yorkshire traces are mostly of smaller links of the ordinary kind, made out of common round iron. Cart traces are generally about ten feet in length, and weigh, according to the strength, from ten pounds to eighteen pounds per pair. Halter-chains, those used with bridles, and others connected with horses used in husbandry, have generally the links twisted, for which no particular reason, beside the fancy of the parties, seems to be assignable. The "back-band," as the carters designate the chain which, passing over the saddle of the horse, supports the shafts of the vehicle, and partially the load, is always twisted, and made flat and square: it is composed of a double series of links, the whole being, when united, heated in the fire; and after being twisted through the entire length, it is hammered into the square form on the anvil.

Ropes have given way to chains less generally in the working of pits, than where both are used for most other purposes. The reason is, that the chain is supposed to break without giving warning, whereas the wear and faults of the rope are generally noticed in time to forestall the danger. *Figs.* 46, 47, 48. are chains used

Fig. 46.

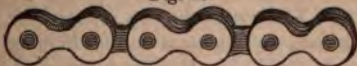


Fig. 47.

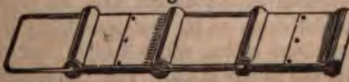
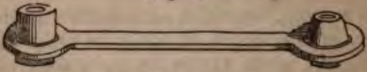


Fig. 48.

in collieries: the last of these is a sort of metal rope, intended to answer the purposes of a hempen rope in the working of mines; also for wells and cranes. It was first made in 1790, by Mr. W. Hancock, of Bingham, near Nottingham, and a premium of fifty guineas was presented to him for his invention. It is made of wire three eighths of an inch thick, twisted into coils. *Fig.* 46. on the smallest scale represents the chain found in the inside of a common watch. *Fig.* 49. is a bar of a chain, similar in principle to that in *fig.* 46.; it was, in 1805, the patent right of William Hawks, a Durham iron manufacturer, whose invention consisted in making chains by cutting the links out of a flat bar by means of a fly press and proper dies, and then fitting into the holes bushes or thimbles to give them the greater strength. A few years afterwards another patent was granted to a Staffordshire iron-master, of the name of Smith, for producing links of a similar form by means of rollers.

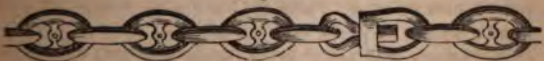
Fig. 49



Latterly, the use of ropes has been largely superseded by the adaptation of chains, not merely for cranes, hauling purposes, &c., but especially for cables; large manufactories for chains of this description having been established in London, Liverpool, Hull, Bristol, and other ports. The use of the best material for this purpose had become so important to the shipping interests, that when, in 1825, Mr. Huskisson proposed in parliament, a reduction in the import duty on foreign iron, he laid especial stress on its indispensability in the manufacture of iron cables, which had of late come into very general use in our ships. The honourable gentleman observed, that "a mixture of Swedish iron was considered of great advantage; and those cables in which it was used were considered the best. Here, then (argued the speaker), a most important benefit to our naval interests might be counteracted or prevented by continuing the present high duties; the reduction of the duty on this article was on every account desirable."

In the substitution of iron for hemp in the manufacture of cables, the two great desiderata, durability and security, are largely secured in the use of the former material: the next object has been to unite with these, economy in the expense and lightness in the article. The amazing stress, which a large ship riding at anchor in foul weather exerts upon the cable, can hardly be conceived by those who have never witnessed its effects. Next, therefore, to the necessity for the iron and the workmanship being such as should not give way, it was indispensable that the links should not draw together at the sides from great longitudinal stress. To secure this end, it has become common, in making the heaviest cables, to place within each link a stout bar to prevent lateral compression, in the manner represented by the annexed sketch (*fig.* 50.) of a portion of the chain of the Messrs. Acraman, of Bristol.

Fig. 50.



It has been contended by some persons, that any advantages supposed to be derived from stays or bars inserted in the direction of the shorter axis of the link are more than counterbalanced by concomitant inconveniences. In the first place, the ponderous chains used as cables are rendered so much heavier by this addition of metal, as to amount to a serious drawback on their acknowledged excellence in other respects: secondly, when the bars are made, as has been the case, with pointed ends, inserted by means of holes or mortices into the sides of the link, they are said to be liable during an extraordinary strain to be driven through or into the sides, and thus to split the iron: and, thirdly, that these bars distending the sides of an elliptical link, so as to prevent it from collapsing at all under any circumstances, the chain is, on this account, rendered rather less than more effective as to its ultimate degree of security.

In 1820, a cause of infringement of patent arising out of improvements on the above contrivance was tried at the King's Bench, *viz*. Brunton *versus* Hawks and Co. The case alleged that the defendants were manufacturing cable chains on the principle of those for which the plaintiff had, in 1813, obtained a patent; an injunction of restraint was therefore prayed for. The solicitor-general, for the defendants, contended that his clients had not copied their link from that described in the plaintiff's drawing, but had merely used an oval link with a stay in it, and which had not only been before patented to captain Brown, but was, as he should prove, a very old invention, and therefore the plaintiff could not have any exclusive right in it. A number of witnesses were examined, to prove that links with bars across had been made before either the plaintiff or captain Brown took out patents for them; and two old nailors deposed that, so long as thirty or forty years ago, they had worked up old links with bars similar to those before them in court. There did not appear, however, any good evidence to prove that any stay had been manufactured before Brunton's on the same principle, namely, instead of being smallest at the ends and thick in the middle, was spread out at the ends so as to overlap the sides of the link; an arrangement, in the opinion of Mr. Bramah, entirely new, and far superior to any stay that had been previously introduced. Dr. Olinthus Gregory, of the Royal Military Academy, Woolwich, was a material witness on this trial, and the substance of his testimony is interesting on the point at issue. He stated that one peculiar merit of the plaintiff's chain cable was, that there was a stay placed across each link, to keep the sides of the link from collapsing; that this stay was made broad at each end, to support a considerable portion of the sides of the link; and that the stay was made to lap nearly half around that portion of the link, so that it was kept from falling out by its own form, without the sides of the link being at all weakened by any indentation into its substance, as was the case with stays formerly put into the links of chains: another peculiar merit of the plaintiff's improvement on chain cables was, that he made those parts of the link that were between the stay and the next adjoining link, in a strait line, as near as may be, and the whole link and stay being in the same plane, that is, without having any twist as captain Brown's links had; by which arrangement, every part of the link was subjected to an equal strain, and was the strongest possible form into which iron could be put for the purposes of a chain cable. The witness stated that he had made experiments on two sorts of chains; one with the link as described in the plaintiff's specification, and the other chain with the common elliptic links without a stay: that he formed one chain of two, by uniting their ends, and subjected them to a great strain, which changed the form of each elliptic link, so as to weaken them essentially; and at length broke that chain without in the least degree injuring the plaintiff's links. The witness afterwards tried, in the same manner, a piece of chain with elliptical links, having a stay in each link, which bore a much greater strain than the other, but finally broke, without the patent chain suffering any injury whatever.

Captain Brown's link is twisted, so as to admit of a certain degree of extension in case of very violent stress: but in the opinion of Mr. Brunel, civil engineer, the weight of a cable chain is more than equivalent to any elasticity which can be given to a link by twisting, in resisting the sudden jerks which are generally occasioned by a rough sea; elasticity cannot be given without weakening the iron, as every change of figure of the iron produced by a strain tends to injure the fibre of the iron and rupture it.

It was with the inventions of captain Brown and Mr. Brunton, and the evidence and result of the trial just mentioned, before them, that in October, 1820, William and Daniel Acraman, two Bristol iron-masters, obtained their patent for "certain improvements in the processes of forming the materials for and manufacturing chains and chain cables." Besides the tendency of the pointed stays to drive into the side of the link, as stated by Dr. Gregory on the trial alluded to, another witness on the other hand took occasion to state that he had seen portions of that part of Brunton's stay which clips or overlaps the link broken off. To obviate both these inconveniences, and at the same time to steer clear of the property of others, the Bristol patentees devised a link on an entirely new construction. They formed cylindrical bars of iron, (see *fig.* 51.) with projections or swells, so placed on the sides at given distances, that when the bar was formed or turned into a link, these projections would fall exactly opposite each other (*fig.* 52.), and thus by their contact form a most effectual stay, perfectly immoveable by pressure or strain. In links of this description it is obvious there are no thin edges or angles liable to be chipped off or worn away. In other cases, as in the section of chain first represented, the projections or swells, being left somewhat lower, are both indented or countersunk so as to form recesses for the reception of a stay, which is introduced, and closed in by pressure, on the bar being turned into a link; the cylindrical part of the chain being preserved, and retaining more strength and substance in this than in any other part of the chain. The extremities of each bar are scarfed, so as to fold over each other a sufficient

Fig. 51.

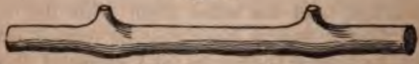
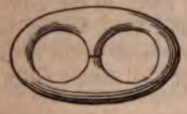


Fig. 52.



length, and by this means give to that part of the link which is shut or welded, additional strength.

From a circular published a few years ago by the celebrated anchorsmiths just named, and exhibiting some scores of testimonies in favour of iron cables, the following particulars are derived:—In comparing these cables with the hempen ones, the first and strongest plea of advantage is their durability, which equals that of the ship itself; whereas our West India traders generally require a renewal of the latter after a second voyage. Another economical object is presented by the room, which is ordinarily taken up by the rope, being open for a greater stowage of cargo; as the chain may be so placed, divided, or extended, as to occupy no otherwise useful space, and may be left on deck without injury by exposure, if necessary. At quays, parts may be applied for mooring; or the cable may lie in the hold, to assist to ballast the vessel when unladen. The facility of working iron cables has been experienced, as fewer hands are employed; and it has been ascertained, that with them vessels can get under weigh by a saving of at least one third of the time otherwise required. A more positive proof of their superiority may be adduced from the assurances of captains, who confess they have no use for their hemp cable, and which may be laid aside by having a *second* bower iron cable; as the ships in the ports of Bristol, London, and Liverpool, bear evidence. On rocky ground the anchorage is effected without injury to the chain, where hempen cables must be cut to pieces, and endanger the vessel. A most important advantage results from the curve, which the chain cables retain to a very great degree, as it strengthens the hold of the anchor by drawing it into the ground; the buoyancy and the contraction of the rope, on the contrary, bearing a direct line from the ship, tends to loosen and unfix it; and as nearly one half of the chain lies on the ground, when any scope is out, it yields to the tossing motion of the vessel, and this to a degree equal to any elasticity which can safely exist in hemp cables.

It may, however, be observed, that no elasticity such as is here spoken of can be acquired without the loss of strength to the material, as the fibres or particles in iron or hemp must be extended, and consequently weakened or broken, to produce it.

Into this chain cable a certain number of swivels are introduced, at proportionate lengths, to facilitate the working of it; and a shackle is placed in each distance of ten or twelve fathoms, the bolt of which is fastened by a pin of composition metal to prevent the corrosion of rust: by this contrivance the chain is shortened or separated according to circumstances. A large shackle is also fixed at one end to be joined to the anchor; and when required, a mooring ring is attached to the end of forty fathoms to moor with two anchors in harbour. The necessity of handling the chain is partly superseded by the use of small hand-hooks; and to prevent the chain from wearing the wood-work of the vessel, the hawse-hole is cased with a wrought or cast iron pipe, and fitted outside with three circular rollers working in a frame. It has, in the estimation of sailors, a good appearance.

In 1822, Mr. Sowerby, of Bishopwearmouth, obtained a patent for a cable chain, with a link having a very broad stay or block of cast iron, through which, and the sides of the link, a cross bar of malleable iron was passed and welded. And for the purpose of preventing the links from entangling, there are small projecting parts or protuberances on the inner quarters opposite to each other. *Fig.* 53. represents the form of Mr. Sowerby's chain.

Fig. 53.

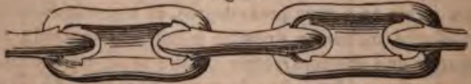
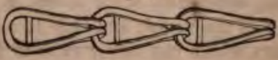


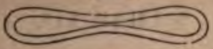
Fig. 54. is a chain constructed by Mr. Gladstone, of

Fig. 54.



Liverpool. The links are first formed in the manner indicated by *fig.* 55., being also welded at the place where

Fig. 55.



the sides are in contact. The link is then bent, and the two circular ends brought against each other; so that when the links are roved together, and a cross bar inserted, the chain appears as in the figure.

The following table, published by a manufacturer in the north of England, shows the proportion of chain when substituted for ropes, with the proof strain of each size: —

Lbs. per Fathom.	Inch Diameter of Iron.		Circumf. of Rope.	Proof in Tons.	Supposed Tonnage.
$5\frac{1}{2}$	$\frac{15}{16}$	Substituted for a rope.	3 Inch.	1	
8	$\frac{3}{8}$		4	2	
$10\frac{1}{2}$	$\frac{7}{16}$		$4\frac{3}{4}$	3	
$13\frac{1}{2}$	$\frac{1}{2}$		$5\frac{1}{4}$	4	20
17	$\frac{9}{16}$		6	5	35
24	$\frac{5}{8}$		$6\frac{1}{2}$	6	50
27	$\frac{11}{16}$		7	8	70
30	$\frac{3}{4}$		$7\frac{1}{2}$	$9\frac{3}{4}$	90
36	$\frac{13}{16}$		8	$11\frac{1}{4}$	110
42	$\frac{7}{8}$		9	13	130
50	$\frac{15}{16}$		$9\frac{1}{2}$	15	150
56	1		$10\frac{1}{2}$	18	170
60	$1\frac{1}{16}$		11	$21\frac{1}{2}$	200
70	$1\frac{1}{8}$		12	24	240
78	$1\frac{3}{16}$		$12\frac{1}{2}$	27	280
86	$1\frac{1}{4}$		$13\frac{1}{4}$	$30\frac{1}{2}$	320
96	$1\frac{5}{16}$		14	33	350
108	$1\frac{3}{8}$		$14\frac{1}{2}$	36	400
115	$1\frac{7}{16}$		$15\frac{1}{2}$	$39\frac{1}{2}$	450
125	$1\frac{1}{2}$		16	43	500
	$1\frac{5}{8}$		$17\frac{1}{2}$	$50\frac{1}{2}$	700
	$1\frac{3}{4}$		$18\frac{1}{2}$	$59\frac{1}{2}$	900
	$1\frac{7}{8}$		20	$67\frac{1}{2}$	1000
	2		22 to 24	77	1200

CHAP. XII.

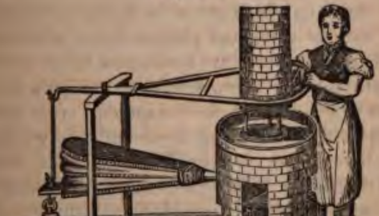
NAILS. — SPARABLES. — SCREWS.

BIRMINGHAM NAIL MAKERS. — MR. SPENCER'S FORGE — TOOLS, FEATS, AND CONTRIVANCES OF NAIL MAKERS. — ROLLED NAILS. — MACHINERY FOR CUTTING AND HEADING SHEET IRON NAILS. — THEORY OF NAIL CUTTING. — NUTS AND SCREWS. — SCREW-NAILS. — MACHINERY FOR CUTTING AND TAPPING WOOD SCREWS.

THE use and antiquity of nails are equally indisputable: it would, therefore, be almost as impossible to say when they were not known, as to specify the precise era of their earliest manufacture among any people acquainted with the methods of working iron. In this country, the nail-makers, in general, inhabit certain districts, scattered, perhaps, over a considerable space, and working one, two, or three persons and sometimes whole families of both sexes, in their little smithies, fitted up with bellows, hearth, a small anvil, and a few other simply formed tools. The appearance of these workshops, and their inmates, in the neighbourhood of Walsall and Wolverhampton, half a century ago, and which is but little changed at present, is strikingly described by Hutton, the quaint historian of Birmingham. "The art of nail-making," says he, "is the most ancient among us. We may safely charge its antiquity with four figures. We cannot consider it a trade *in*, so much as *of* Birmingham; for we have but few nail-makers left in the town: our nailors are chiefly masters, and rather opulent. The manufacturers are so scattered round the country, that we cannot travel far in any direction out of the sound of the nail-hammer. But Birmingham, like a powerful magnet, draws the produce of the anvil to herself. When I first approached Birmingham from Walsall, in 1741, I was surprised at the prodigious number of blacksmiths' hops upon the road; and could not conceive how a ountry, though populous, could support so many people f the same occupation. In some of these shops I observed one or more females, stripped of their upper garment, and not overcharged with their lower, wielding the hammer with all the grace of the sex. The beauties of their face were rather eclipsed by the smut of the anvil; or, in poetical phrase, the tincture of the forge had taken possession of those lips which might have been taken by the kiss. Struck with the novelty, I enquired, 'whether the ladies in this country shod horses?' but was answered, with a smile, 'They are nailors.'"

To economise coals, shoproom, &c., two or three nailmakers commonly occupy but one hearth, using the same fire and the same bellows in turn. Still farther to extend this facility of co-operation, and to secure other desiderata, especially in the manufacture of horse-shoe nails in a charcoal fire, Mr. Spencer, of Belper, obtained a patent, in 1824, for a circular forge, around which five or six persons may conveniently work at the same time. *Fig.* 56. is a perspective representation of Mr. Spencer's

Fig. 56.



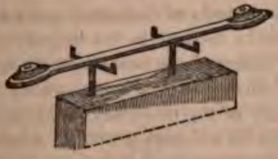
forge; the mode of constructing which, and its advantages, must be apparent on the slightest inspection. Although as much room is gained by this ingenious arrangement as in most cases can ever be necessary, it might not be difficult, by placing Lindley's circular bellows *in-*

side the lowermost part of this forge, to leave the whole circuit of the hearth entirely free to the workmen.

The patentee, after describing the construction of this forge, remarks:—" There are many novel features in this invention, which do not strike the reader on the first perusal. Nothing is represented to his mind but bricks, mortar, and iron, in the form of a forge; with which substances forges have been erected since the days of Tubal: while to the operative man, who has to preserve the quality of pure iron uninjured, this invention presents a most valuable acquisition. In no other forge (excepting a hollow fire) can pure wood charcoal be used; no other forge is constructed without a back; no other forge has a grating to keep the fire clean, and prevent the accumulation of clinker; no other forge will admit of the same number of workmen being employed at the same time; no other forge can be erected at so little expense."

The form of the hearth or forge, however, is of secondary importance to the quality of the material worked therein. Good nails are manufactured out of the best foreign or native iron, which is prepared by being rolled or slit into rods of the proper strength, according to the size of the nails which are to be drawn out of it. These are of various sizes and shapes, from what are called brads or spikes, which are sometimes made nearly a foot in length for the shipwright's or builder's use, to the smallest tingle nails of about a quarter of an inch. The anvil upon which the nail is actually drawn out of the rod by hammering, is a small cube of steel, with a surface of but a few inches in extent, and is itself inserted into a cast or wrought iron block, weighing from one to two cwt. — the whole of this larger mass being generally surrounded with stones, and imbedded in smithy-slack, so that only the small anvil is seen. The hammer used is larger or smaller, according to the size of the nails to be formed; its usual form is the frustrum of a cone, the smaller end being the face, which, instead of forming a horizontal plane, as in the case of an ordinary round hammer, is inclined or sloped considerably towards the handle. The degree of this obliquity, the weight of the hammer-head, the size and shape of the handle, &c., are matters of nice consideration; one nailor being rarely able to work comfortably with another man's hammer: hence, as they are somewhat given to tramping from place to place, each workman generally carries with him a favourite hammer, which, like the fabled mallet of Thor, is both the symbol and the agent of the owner's power. When the nail has been drawn out to the proper length and form upon the anvil, it is cut off the rod, by striking it upon an upright chisel or *hack-iron*, and instantly inserted into an instrument called a *bore*, in order that the head may be formed while the iron is yet red hot, for the shank is drawn out, the nail cut off, and the head flatted at a single heat. This bore is a piece of strong iron, ten or twelve inches in length: near to each end there is a knob or swell of steel, perforated to the size of the shank or collar of the nail, and countersunk, so as to correspond with the head. It is by inserting the nail through one of these holes or bores, and striking it with the hammer upon the thick end, that the head is formed, whether beaten flat, or left with a quarter-formed rise in the centre. The bore, when out of the workman's hand, is placed beside the anvil, upon two brackets, as represented in *fig.* 57. Although the method of working is pretty much the same with different individuals, the degree of perfection and neatness displayed in the formation of so simple an article as a nail, varies very considerably in different hands.

Fig. 57.

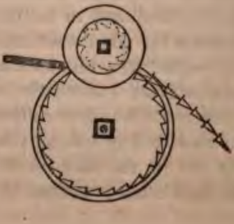


The nailors among themselves are fond of relating instances of great personal dexterity. The following has been recorded in the Mechanics' Magazine for 1828:—James Leighton, a nailsmith in the employ of Mr. Thomas Gillies, ironmonger in Stirling, lately undertook, for a trifling bet, to make 17,000 double flooring nails, 1200 to a thousand of 20lbs., for two successive weeks; a task which must, to all who have any knowledge of this trade, seem scarcely credible. The workman finished his first week's task by three o'clock on Saturday afternoon; resumed his labour on Monday morning, and concluded his second week's task with even more ease than he did the first. Those who do not understand the nature of the work may form some idea of the undertaking when they are informed, that the above quantity is allowed to be as much as three ordinary men can perform without difficulty; and that, allowing twenty-five strokes of the hammer (which is 2lbs. weight) to each nail, including the cutting of the rods into a size convenient to be handled, and re-uniting them when too short, there were no less than 1,033,656 strokes required before the task could be completed. In addition to this, the workman had to give from one to three blasts with his bellows for every nail he made, had to supply the fire with fuel, and had to move from the fireplace to where the nails were made, and *vice versâ*, upwards of 42,836 times. The workman entered into his fifty-first year on the day on which he commenced his task, and had been upwards of forty-two years a nailor; and in 1800, when in Ireland, in his majesty's service, beat one who was reckoned the best workman in that country by 770 nails, during twelve hours' work.

If the quality of the material be of importance in the making of nails for ordinary purposes, much more is this the case in reference to those that are used for the fastening of horse-shoes. The iron for this purpose ought either to be of a good foreign mark, or the best British that can be obtained. Many of the old nailors in the north of England speak with enthusiasm of the superior nails which they used to produce when working the Russian C C N D, and next to that the rich Cumberland iron. As iron smelted with charcoal undoubtedly works the most kindly, so it is certainly the best when the same description of fuel can be used during the working of it: this method, however, on account of the expense and inconvenience attending it, is seldom adopted on a large scale; and, indeed, coal of a fair quality in general serves well enough for ordinary purposes. Of late years the horse-shoe nail-makers have hit upon a simple contrivance for keeping the iron longer at a deep red heat, by which the operation of forging it is materially facilitated. Each workman has fixed up (generally aloft) at a small distance from his smithy, a small circular bellows, about a foot in diameter, leathered so as to rise from twelve to eighteen inches; from this machine an ordinary pipe descends, at the bottom of which, making a right angle, is affixed a small tube with a quarter-inch bore, the orifice of which just lies upon the edge of the small anvil. When the iron, after having been heated sufficiently in the fire, is placed upon the anvil, the workman, by means of a treddle suspended to a crank above, raises the bellows-board, which, upon the removal of his foot, sinks slowly down, according as it is weighted; a soft blast being meanwhile blown upon the hot iron, it is made, by reason of the oxygen of the air-jet, to retain its generous heat for a much longer time than otherwise it would, the operation of forging being rendered by this means both more pleasant and successful.

In the manufacture of nails different kinds of machinery have been introduced to facilitate the process. In 1790, two patents for what were called "new modes of manufacturing nails" were obtained by different individuals. The processes were as nearly identical, as they were, in many respects, alike practically inefficient. The former operation consisted in having the figures of nails of different sorts cut in the surfaces of rollers, exactly corresponding to each other; so that by passing a sheet or rods of iron between these imprinted rollers, "several strings of nails," or even "what may be called a sheet of nails," may be quickly formed. Nails were also to be made on this principle, by having the impressions cut in dies, and the metal pressed into the cavity by any mechanical power. The other patentee proposed to draw out his metal into the form of a wedge, and cut the nails out of it with a bed and punch at a fly, and likewise to head them by a stroke with a concave punch at the fly. He also includes in his specification, the "method of manufacturing some sorts of nails, by cutting them out of, or from, plates of equal thickness, and afterwards pointing them, either by a hammer or other pressure." In common, however, with the individual first alluded to, this deponent proposes to "make divers sorts of nails, by passing the iron, or other metal, between two rollers, having impressions, according to the different forms, cut into the surface of one or both of the rolls; whereby a sheet is procured, having, in some measure, the appearance of nails;" and which nails were to be cut out with a punch. The principal, and, indeed, the most successful of these machine attempts, in the way of direct imitation, have been to supersede the hammer wholly or in part, by means of rollers, either producing sheets of nails, so that they required to be separated with a fly or with shears, or strings of nails much more nearly finished. The method of producing this latter sort will be apparent from the section of a pair of rollers represented in *fig.* 58. As in the formation of most articles

Fig. 58.



in which tenacity is desirable, iron is much improved by hammering; and as this is particularly the case in the making of nails, those that are produced entirely or partially by rolling, or by any means but the forge, are reckoned very inferior to others that are made under the hammer, and the prices of each sort vary accordingly. It requires, however, more experience than falls to the lot of many retail purchasers of nails, to judge between the different kinds; and more honesty than is always possessed by certain dealers to prevent them from at least mixing up the spurious with the genuine articles, especially in orders for exportation. Large quantities of cheap nails are cast of common pig metal — these, of course, can never be mistaken for wrought ones: lath nails are generally of this description.

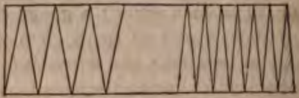
Another description of *cut-nails* are made as follows. Sheets of iron of the proper thickness are cut across by a pair of cutting edges, which are set in motion by machinery; the breadth of these strips is equivalent to the length of the nails to be produced from them; the strip, for the convenience of turning, is fastened into a pair of grips attached to a wood shank, resting, when in use, upon a support immediately behind the workman. The nail machine consists essentially of a pair of cutting chisels or edges, which work perpendicularly, parallel to each other; a gauge to determine the breadth of nail; a pair of grips, into which, at the time, the wedge of iron falls, and where it is firmly held, until a small horizontal hammer strikes it, and produces the head, when it is dropped into a box beneath. Brads are not headed, but are simply cut out of each other; that is to say, a deficiency in the parallelism of the cutting edge produces the head, and prepares for the head of the next brad to be cut therefrom. Glaziers' brads, being simply wedge-shaped pieces of iron, without any head whatever, are produced by the simple operations of the chisels or cutters. When tacks are *blued,* they are done in quantities, by exposing them to heat in an

oven or muffle, or upon an iron plate. When
japanned the ordinary process is employed.

The term sparrable, or sparrow-bill, as us
head of this chapter, describes a well known
the form of which bears a sufficient resemblan
mandible of a familiar bird, to account for t
lation. It is here mentioned in this particula
not because it is in itself of so much conseque
the articles, as in the history of this extensi
facture, having undoubtedly led the way to th
universal adaptation of machinery in the pro
certain kinds of nails which obtains in many pa
United Kingdom. A pretty accurate idea of t
of producing this simple description of spar
spriggs, may be formed by taking a slip or
paper, half an inch wide, and of any length, a
pair of scissors cutting from the end triangula
in the form of exceedingly fine wedges, turnin
terial over after every cut, in order that the
broader part of every clipping may be taken
point of the preceding one, and *vice versâ.*

The stronger sections of the annexed cut rep
profile of the common sparrables that are now u

Fig. 59.



used by the shoemakers, and the slighter secti
are called spriggs, used as well by that class of
as by many others.

If we transfer our idea from a pair of sciss
worked by the fingers, and the slip of common
the fly with its cutting punches, and rands of
we shall have the theory of the nail-cutting bu
will be obvious, too, that not only with a fly,
pair of stout shears, nails of almost any si

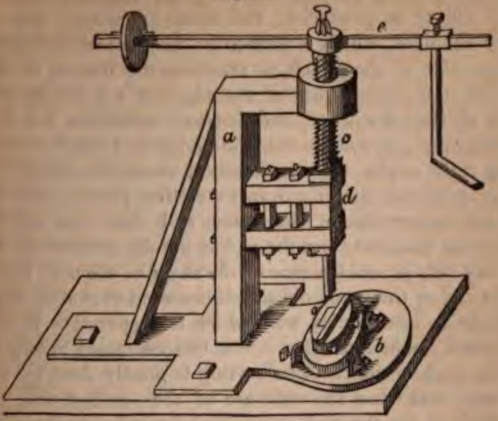
might actually and easily be cut out of rolled metal; by the latter process, however, they would all be curled or bent, which is not the case with those cut by punches. It must be equally apparent, that by using wider strips and stouter material, the size of the nails may be increased indefinitely. The greatest proportion, however, of the nails manufactured on this principle, are from a barleycorn to about three inches in length. Although this method of making nails originated in the production of the kinds first mentioned, and which are without heads; yet the practice of heading cut nails soon followed, and is now almost every where practised. The introduction of machinery into this branch of trade affected in no slight or favourable degree the production of similar articles by the old process of forging: this roused the indignation of the nailors, and they were not slow in expressing themselves very harshly towards a discovery which had so largely superseded the hammer and the hearth. The Dublin nail-makers went to still greater lengths in their hostility; so that on the introduction of a machine which had been made in Birmingham, where nail-cutting has been carried to the greatest perfection, the local nailors attacked the house of the importer, seized and broke the machine to pieces: the consequence of this course of proceeding has been, that the nail trade has decayed in the seat of its ancient prosperity, and Ireland imports large quantities of cut nails from this country. As nails are an article the manufacture of which is so simple where the material exists, and so economical where labour is cheap, they are made in most countries where they are used; especially in America, where machinery has long been brought to perfection: the nail trade is, therefore, less important as connected with our commercial interests, than as furnishing a product of immense value for home consumption; still the exportation is considerable, especially to the colonies and to the East: Holland, however, furnishes large supplies all over the continent, Rotterdam being a great nail mart, the principal manufacturers fo which reside at and about Charleroi.

As the quality of the iron is a consideration of grea importance in the article of wrought nails, it is still more so in the material of those that are cut by machinery, particularly in such sorts as are headed. The bes charcoal iron therefore should be used ; though in nail making, as in every other species of handicraft, diminutio of price leads to deterioration in the article ; and th dealers in brads and sparrables, with more temptatio to use middling iron than many other tradesmen, a probably not the less prone to do so. As already observ the sheet iron, previous to the operation at the fly, is into strips or rands, varying in thickness and brea according to the size of the nail to be produced, length being of course determined by the width of t slip. These slips are cut out of the sheet either wi large shears, or by the means of grooved rollers ; ran to any prescribed size cut in the latter manner being fu nished by the Staffordshire iron-masters on terms nearl identical with those upon which the entire sheet is sol As, however, in the laminating of iron, the elongatio of the sheet is inseparable from a corresponding directio of the fibre or grain of the material, and as, in slittin up the sheet with circular cutters, the section is almos always longitudinal, the nails cut from rands of this sor are necessarily cross-grained and brittle, especially whe headed. On this account many nailors prefer to cut u their material themselves, even though under somewha disadvantageous circumstances.

The fly used by the nail-cutters is similar to that whic is found in many manufactories where metal is wrought and of which *fig.* 60. is a representation.

In order to avoid encumbering the cut with figures o reference to every particular part thereof, the construction and working of this extensively useful instrumen will be readily understood by the following explanations The body of the fly *a* consists of a massive cast-iro pillar, having at the top an arm or head containing a

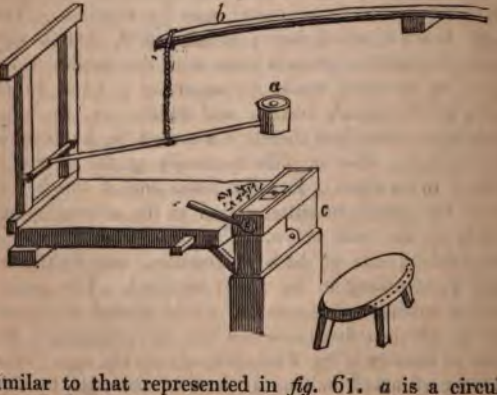
Fig. 60.



brass bush through which the screw works, and a large plate or foundation at the bottom, by means of which, through cottor holes at the corners, the whole is screwed firmly to the work-bench: from this foundation plate rises the bed or boss *b*, having four screws to hold in its place whatever die or cutter may be required. The main screw *c*, which has a double worm, that it may move through the greatest space with the smallest revolution of its axis, works by means of a knob on its point in the square box *d;* and which box, by being accurately fitted into directors attached to the body of the machine, rises or falls vertically as the screw is turned in its place. Into the lower end of this box is fitted the punch or cutter suited to the corresponding article in the boss below. The handle or lever *e* is weighted at one or both extremities. and lightly or heavily, according to the power required. The punch used in cutting nails consists of a cube of steel, the upper part of which is fitted into the box above described, the other extremity being filed obliquely on the side to the distance of about half an inch from the ends, by this means forming a shoulder exactly the size and form of the nail to be produced: the outer or cutting edge of this shoulder, which is formed by the vertical surface or front side of the punch, is made by the motion of the fly to pass close by one of the edges of a quadrangular bar of steel, hardened, and fastened across the bed in a horizontal position, so that the punch and this bar making right angles with each other, every descent of the former carries the groove in its vertical surface past the sharp square edge of the latter, and thus cuts off the amount of a nail from the end of the slip presented. As every cut, in consequence of the shape of the nail, leaves the end of the metal oblique, it is turned over after every stroke. The celerity with which this operation is performed would astonish a person unaccustomed to witness this kind of work. The cutting is mostly done by women: and when the nails are of the smallest size, the knack of the fly with every stroke nearly equals in the rapidity of its repetition the ticking of a watch.

By whatever methods they may be produced from the sheet, cut nails are generally headed by a contrivance

Fig. 61.



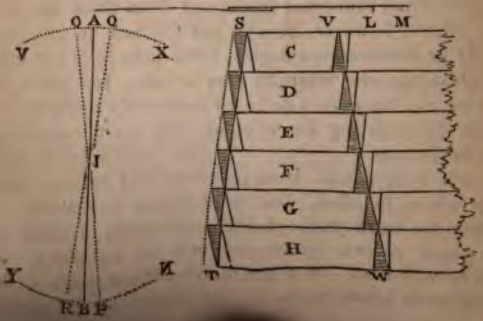
similar to that represented in *fig.* 61. *a* is a circular hammer, or head of metal, weighing from seven to fourteen pounds, and cast upon the extremity of an arm of iron about three feet in length, the other end of which consists of a small cross bar, working with ears or staples in two upright cheeks of wood placed against the wall of the workshop. This arm is suspended in nearly a horizontal position, by means of a rope connected with a springing pole *b*: this pole is a stout, flexible ash sapling, brought over a balk at the ceiling of the workshop, in a manner similar to that of a wood turner's throw. *c* represents a pair of massy cast-iron chaps, bushed with two bits of steel to bite the nail, and firmly fixed below into an upright block of wood. Over the upper part of these chaps is placed a wrought-iron box or collar, through one end of which passes a screw attached to a spanner or lever, and which, by being brought forwards or turned back, pinches the nail between the bits, or sets it at liberty after it has been headed by a single stroke of the hammer, which is brought smartly down upon it for this purpose. This work, which is generally performed by a woman, sitting close up to the block in front, is despatched with amazing quickness.

The perfection of cut nails, as to workmanship, consists principally in the shank being well formed and free from fash, the point keen and perfect, and the head as nearly circular, and having the stem as exactly in the centre, as possible. It is uncommon not to find in every parcel of nails numerous deviations from these desiderata: where, however, this is not the case in any unsightly or inconvenient degree, these nails have not only the advantage over wrought ones in price, but often for use also, the roughness or beard necessarily marking the angles, contributing essentially to one main excellency — adhesiveness.

It will be apparent, from the account of cutting single sprigs above detailed, that in forming a machine to facilitate the work through the application of steam or other power, several precautions will be necessary. It would be very easy, by a common vertical motion, depending either upon eccentric head gear or the simple lever, to work a straight-edged punch so as to cut, from the ends of a number of strips of metal ranged beside one another, little pieces which should be of uniform thickness throughout: but these would be equally square at both ends. It is obvious, however, that by giving an oblique line to the cutter as compared with the ends of the metal slips, or by presenting the slips themselves to the cutter in an oblique direction, the portions chopped off would be sparrables, more or less acute in their angle, according to the obliquity of the cut. Still, were the slips to be pushed forwards, and another series of pieces to be cut off, these would neither be square nor triangular like the others, but rhomboidal: unless, after every cut, the slips were turned over, which would divide the rhomboid and produce pointed sprigs.

As, however, no machinery has yet been adapted to turn over a number of slips of iron (however easy to turn a single slip with the hand), recourse has been had to the means of giving a peculiar motion to the cutter, which exactly meets the difficulty. The annexed diagram will illustrate the principle upon which most of the engines for cutting nails by power are constructed. The edge of the cutter is indicated by the line A B, *fig.* 62., and the slips of sheet metal by the letters

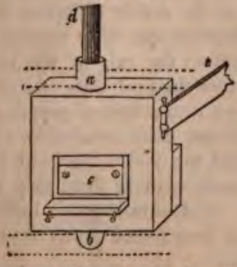
Fig. 62.



C D E F G H. If we suppose the cutter, or rather the cutter-frame, to move upon a pivot at I, and K to be a rod attached to it at A, and free to move horizontally, it will be obvious that a small cam, revolving between the projections L M, will slide the rod backward and forward, and, consequently, place the edge of the cutter alternately in the direction of the lines O P and Q R. If, therefore, the slips be together advanced under the edge of the cutter when in the direction of O P, and a stroke made, it is plain that the bits of metal chopped off will be in the shape of the shaded sections marked from S to T. When, by another semi-revolution of the machinery, the edge of the cutter is moved into the line Q R, and the slips advanced as before, the next stroke will chop off (supposing them at the ends) the series of sprigs shaded between V and W; and this alternation of heads and points will be presented to the cutter until the whole length of the slips is cut up. The sprigs will of course be more or less acute in their shape, as, by altering the stroke of the rod K, the cutter is made to traverse a greater or a lesser extent through a circle, the segments of which are marked by Z X, Y N.

Fig. 63. is a front view of the frame in which the cutter works. *a* is a turned neck neatly fitted into a bar of cast-iron above, and terminating with a stout pivot *b*,

Fig. 63.



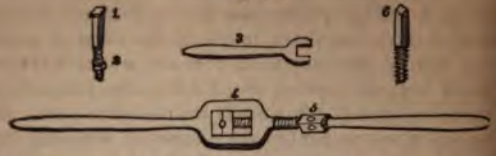
let into a similar bar below; *c* is the cutter about three inches wide, and which is made to move up and down past the sharp edge of a piece of steel adjacent, by means of the rod *d* passing through the neck of the frame to which the reciprocating motion already described is given by the bar *e*. The slips of sheet iron are directed to the cutter by being placed upon a level plate, exactly opposite its edge; and they are pushed forward either by weighted strings or other contrivances. It will be observed that a cam is used in preference to an eccentric wheel in moving the cutter-frame horizontally, because as there are two periods in its revolution, when it does not touch the lever, and, consequently, the frame has no motion, those are the moments when the cutting stroke is contrived to be given. One of these machines is made to give about 160 strokes in a minute, consequently when six slips are presented at once, each cutter chops off upwards of 900 nails in a minute; which, taking into account the number of machines in a single establishment, may give some idea of the prodigious quantity daily manufactured in this country. It may be mentioned, that some ingenious mechanics have succeeded in constructing apparatus which not only cut the nail from the strip, but catch and head it at a single operation.

It may be mentioned, that about ten years ago a patent was taken out for a fanciful peculiarity in bolts and nails to be used for ships and other fastenings: it consisted in giving to the shanks a *twisted* form, or, in the terms of the specification, in "making the sides and angles to wind round the axis of the bolt or nail in a screw form, so that the said bolts or nails, when in the act of being driven into a hole of proper size, revolve on their axis, as they are made to advance by the force applied to them, and the pieces therewith bolted together are held much more securely than they would be with common bolts." It does not appear, however, that these torsion nails have ever found much favour with workmen of any class.

An extremely useful succedaneum to the common nail, but one of much more recent invention, is the wood screw, or, as it is sometimes called from its affinity, the *screw nail.* This article, especially in work not admitting of much strength, or to which the hammer could not be applied, not only holds into the substance of the material with the greatest possible firmness, but, as just remarked, allows of being safely insinuated in numerous cases where, on account of the delicacy of workmanship or other causes, a nail could not be driven successfully: of this description are most kinds of cabinet work, articles containing panes of glass, and numerous other things of the like sort. Screws, however, of this description are more generally used instead of the smaller than of the larger sorts of nails, the latter being without difficulty driven into heavy timbers; whereas screws of considerable diameter, on account of the increased friction produced, when compelled to make their way in a hole of large dimensions, become almost unavailable, particularly if the material into which they are driven be very hard. In cases of the latter description, therefore, where these screws cannot be forced, nor large nails advantageously be driven, it is common to use what is designated *a screw and nut,* consisting of a bolt of any length and thickness, having at one end a head of sufficient size, and the other end screwed or tapped, so as to fit a square nut or knob, likewise tapped to suit. In using these screw-bolts, a hole is bored quite through the timbers to be fastened, into which the bolt is driven to the head; and upon the other extremity the nut is tightly screwed up by means of a spanner. These screws and nuts, when large, are made by the blacksmiths, with the following tools:—

In *fig.* 64., 1 represents the screw-bolt; 2 the nut; 3 the spanner; 4 is the stocks, at the middle of which are two hardened steel dies, upon which is cut the screw intended to tap the end of the bolt; 5 is one arm of the stocks terminating with a stout screw, by means of which the dies are pressed close together, to make the tapping more perfect; 6 is the steel instrument used for tapping the nut: it is sometimes made rather taper, and always

Fig. 64.



nicked across the threads, to assist it in cutting the iron. It is used with an horizontal lever similar to the stock. But to return to the screw nails, which are more immediately the object of the present description.

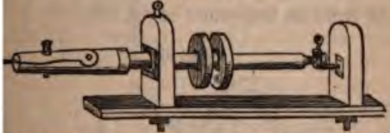
The blanks for wood screws are generally forged by the nailors, much in the same manner as the nails themselves. Instead of the shanks of the former being left square, as those of the latter mostly are, they are first sized on the anvil, and then rounded more perfectly by swaging; that is, by placing the article between two bosses, each having a semicircular concavity on its face, and which when made to close by striking the head of the uppermost with a hammer, gives a cylindrical shape to the blank screw: it is then cut off the rod, and the head formed in a bore, in the same manner as a nail head. In 1818 a patent was granted to Edward Wolley, of Bilston, for making these "screw-forgings," as they are called, from *round* iron, which, being cut into proper lengths, these were pinched when red-hot between the chaps of a vice, or a pair of clamps, and the heads formed by a stroke with a fly or a press. The advantage claimed for these blanks over those forged at the anvil, was, that they would be regularly and uniformly rounded and tapered, though from the specification it does not clearly appear how the latter desideratum is effected. A patent for making these screws of wire had been taken out three or four years before, in connection with a process of cutting, hereafter mentioned.

The methods adopted for the production of the worm, or thread, of the screw, are various; and, however simple the effect produced, not easy to be described: indeed,

the machines exhibit such a degree of com-
as almost to set the intelligibility of ordinary
and description at defiance. The first and
nple course, and that which would most ob-
suggest itself in the infancy of screw-cutting,
bring out the threads with a three-square file.
plan was too tedious, expensive, and imperfect
ontinue; and accordingly it has for many years
irely superseded by cutting and tapping.

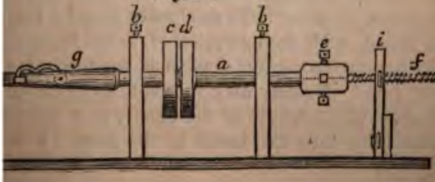
-forgings as they come from the hammer pos-
gree of hardness which would render the pro-
utting harsh and difficult, were they not softened
g heated, a number together, red-hot. This
n of annealing being performed, the forging is
by the point into a jointed iron chuck or nipper,
on a spindle, and opening and shutting by
f a screw, as in *fig.* 65. While the article is

Fig. 65.



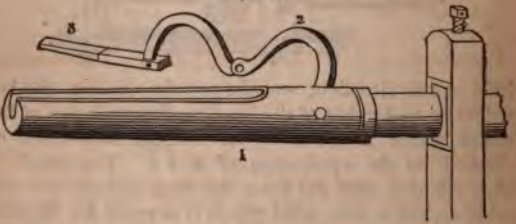
his situation, and the spindle revolves, the be-
under side of the head, and that portion of the
hich is not to be screwed, are brightened or
by the application of a file. The blank is
ased, filed flat upon the head, and the nick cut
ircular saw, after which it is ready for the cut-
ine, of which *fig.* 66. presents a front view.

Fig. 66.



This machine consists of a steel spindle or maundrel, *a*, about twelve inches long, and revolving between collars in the puppets *b b*, in the manner of a common lathe: those portions of the spindle which are between the collars, and for two or three inches beyond, are made very true and cylindrical, to allow the spindle to move backward and forward. This spindle carries two pullies: one, *c*, being fast, to give motion; the other, *d*, loose, to carry the band or strap when off the former. The right hand extremity of this maundrel, or what is technically termed the tail, is finished with an iron box, *e*, fitted with four small screws, for the purpose of fastening therein the regulator screw, *f*. This screw is five or six inches in length, and as its character determines the thread of the screw to be cut, it is itself made coarser or finer according to circumstances: *g* is the iron chuck or holder, occupying the nose of the spindle, and in this the screw is detained during the process of cutting. Its construction will be better understood from an inspection of *fig.* 67.

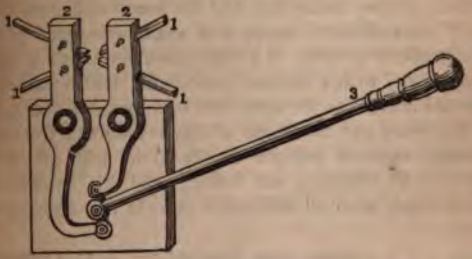
Fig. 67.



No. 1 is a stout cylindrical box or tube of iron, about six inches long and two in diameter, one end of which is fastened to the spindle as already stated; the other end is closed, with the exception of a slit from the circumference to the centre, somewhat resembling a common key-hole. Exactly over this slit, and extending three-fourths of the length of the chuck, is an opening for the admission into the inside of the trap. 2 is this trap consisting of two iron crooks, not unlike the shackles of a hang lock, with a joint between them, and attached to the chuck by another joint towards the spindle. 3 is a sort of chisel-shaped spike, fixed to the opposite end, the edge of which, when the trap is shut down, just reaches to within the thickness of the screw-head, of the extent inside the cavity.

In the front view, *h* indicates the position of the cutters, of which, with the contrivance by which they are brought into use, *fig.* 68., is a front representation.

Fig. 68.



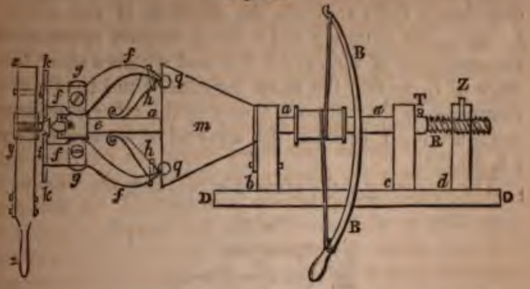
These cutters, 1 1 1 1, two only of which are edged so as to act upon the iron, the remaining two being merely designed as counter points to keep the screw to the cut, are inserted through the metal frames 2 2, and fastened by means of four short stiff screws. These frames move on joint pins, and by the operation of the lever 3, the cutters which they carry are brought into contact with the shank of the screw, and made to bear upon it with a greater or lesser degree of pressure, according to circumstances. Directing points, somewhat resembling these cutters, and attached to the hindermost puppet *i*, by joints, are made to close upon or recede from the regulator screw *f*, with a lever like that by which the cutter-frames are worked. These levers are connected by a horizontal bar (not shown in the sketch), so that both can be depressed or elevated together, and thus the cutters and directors be at once applied.

When a screw is to be cut, the trap is lifted up, and the blank placed with its nicked head against the chisel-spike, the whole being then shut down into the centre of the chuck; after which both the levers are depressed, and the strap transferred from the loose to the fixed pulley. The guides now acting upon the regulator screw behind, force the blank screw between the cutters, the edged ones cutting out the interstices of the thread according to their size: when the thread is traced far enough along the shank, the levers are elevated, the spindle pushed backward, and the screw either released, or, if not sufficiently deep, it is again submitted to the action of the cutters. In some cases, by using a regulator screw, with a reverse motion, the cutting is commenced nearest to the head and terminated at the point. A few years ago the pacha of Egypt obtained from this country eighteen engines of the kinds just described, namely, six dressing, six nicking, and six cutting engines, along with all the requisite tools for forging the blanks.

In 1817, a patent was obtained by J. G. Colbert, a metropolitan watchmaker, for "certain improvements in the method of making metal screws, for the use of all kinds of wood-work." Mr. Colbert proposed to form the screws out of wire of the proper strength, by first cutting it into lengths, and then producing the heads by hammering and spreading out one end of these pieces, while pinched in a vice, similar to the process of riveting.

The thread is cut, and the head turned ready for the making of the nick or cut, by the machinery represented by the figures 69, 70, 71. — *a a a* (*fig.* 69.) is a steel axis, working in the uprights or puppets *b c d*, on a frame D D. At the extremity *e* of the axis, a piece crosses it at right angles, to which are affixed, by screws and nuts, the two bent arms *f f f f*, which move on the screws *g g* as centres; each is furnished with a strong

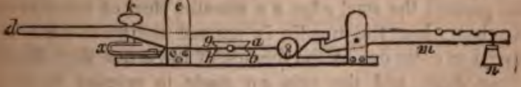
Fig. 69.



spring *h*, which bears against the axis, and presses the corresponding extremities *i i* strongly towards each other: in each of these extremities *i i* is fixed, by dovetailed slides and screws, a steel cutter *k*. *m* is a conical tube, which may be moved forward along the axis *a a a* (towards the end of which the bent arms *f f* are fixed), for the purpose afterwards described. The screw intended to be turned and cut is placed between the cutters in the holding-pieces *f f*.

Fig. 70. represents the side elevation of a metal frame, of two parts, *a* and *b*, opening from each other on the joint at *c*, by the handle *d*; the upper or moveable piece

Fig. 70.



a moving between two cheek pieces, of which one is seen at *e*. Into each of these pieces *a* and *b*, and in a direction at right angles to their length, is placed in dovetailed grooves, and there secured by screws, a steel cutter, having teeth in the usual way, for the purpose of cutting a screw thread on a metal cylinder introduced between them: these pieces are shown in the figure at *g h*, and are sufficiently held together by the lever and weight *m n*.

This part of the machinery is placed, when in use, in a direction at right angles to the direction of the axis in *fig.* 69.; the cutters *g* and *h* being directly opposite to the extremity of the cutters *k k*, and within a small distance of it, so that the screw introduced and held at one extremity by the cutters *k k* may by the other extremity introduce itself between the serrated or toothed cutters *g h*, *fig.* 70.

The following is the manner of working the machine;

Fig. 71.

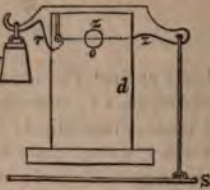


fig. 71. is a front elevation of the upright piece *d*, or back puppet of *fig.* 69., showing an aperture *o*. A thin steel edge-piece, *z z*, moveable on a centre *r*. It has a suspended weight W, at a little distance beyond the centre, and a treadle S affixed to the other extremity. A steel screw R (*fig.* 69.) is affixed to the axis *a a*, and secured by a small screw T; this screw R passes through the aperture *o*, without touching it: when the treadle is not pressed the steel edge *z z* remains clear of the screw R; but when the treadle is pressed the steel edge is forced to enter one of the threads of the screw R. This being done, and the axis *a a* made to revolve by the operation of the bow B B on the pulley, or by any similar contrivance, the axis being cylindrical throughout its whole length will, by the action of the screw R on the fixed edge *z*, make a forward progress towards that part of the machinery (*fig.* 69.) marked *x y z*; and the rate of that progressive advance will be always regulated and adjustable by the fineness of the screw R, which may be changed at pleasure as the thread may be required to be coarser or finer. This progressive advance of the axis *a a* will thus force the screw to be cut, placed as already described at *k k* into the small space between the screw cutters *g h* (*fig.* 70.). The conical piece *m* is then brought forward over the bent arms *f f f f*, so as by this means the cutters *g g* and the cutters *k k* are loosed a little: the new screw, which was before held by the cutters *k k*, is now released from them. The screw being detained by pressing the lever *d*, and the conical piece *m* moved backward, the cutters are made to revolve, and thus turn the level or back of the head of the screw, while the small cutter or chisel * at the end of the axis turns flat the surface of the head of the screw. Mr. Colbert makes the nick in the head by placing a number of the screws in a frame, and cutting them at once with a steel saw.

Aughtie of Cheapside, who had a patent for coffins almost forty years since, included in his specification a peculiarity in the head of his screws, which is not without its advantages in connection with that security of the dead, which it is in many cases so difficult to effect. Mr. Aughtie's screw (*fig.* 72.), after being quarter cut on the head (*fig.* 73.), is on one side of each of the divisions filed away to the bottom of the nick, so that a screw-turner will only operate upon the screws in one direction, that is, to force them home; it being impossible to withdraw them by any attempt to turn them the reverse way.

Fig. 73.

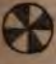
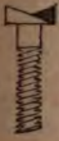
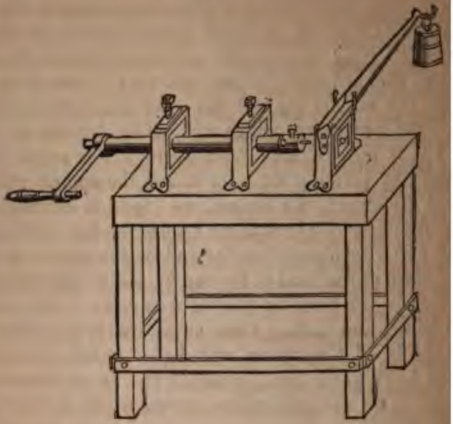


Fig. 72.



There is another method of manufacture largely adopted in the production of an inferior kind of screw, which consists rather in tapping than in cutting the thread. The machine for this purpose, which is both simple and economical, will readily be understood from the annexed cut. Upon a strong table of wood, *fig.* 74., elevated on four legs, are fixed three cast-iron puppets or uprights; through the collars in two of them an axis is made to work freely, by being turned perfectly cylindrical. One end of this axis is terminated by a handle, and the other carries a metal chuck, which opens with a

Fig. 74.



joint to admit the head and shoulder of the screw bl about to be tapped. The third puppet contains, betw moveable pieces of metal, two steel dies, cut accord to the thread designed to be produced on the bla A weighted lever is allowed to bear upon these holders, the screw blank meanwhile being worked ba wards and forwards between them until the thread sufficiently elicited. In many places, a machine of description contributes mainly to the support of a fam — the husband forging the blanks, which are filed nicked, and afterwards screwed in the above manner the wife and children. These articles are sold on Saturday night to the factors, on terms which afford too often only the means of a miserable subsistence, unfitly represented by the quality of the screws by wh it is earned!

Many of the larger sort of scr [illegible] n cast. this operation the chief diffic [illegible] extricati of the models from the sand [illegible] ourse, t require to be moulded horizontally in halves. It may be interesting here to remark, that some years ago Mr. Maullin, a Staffordshire screw-maker, invented a method of withdrawing bed, wood, and other screws from the sand in which they had been moulded, which displayed considerable ingenuity. His plan consisted in a contrivance, by means of which the model-screws, after appearing with their entire length through a plate, upon which the moulding-box was placed, were at once turned round and drawn downwards, by a motion corresponding with the rate of the thread. A description and figures of the machine by which these screw-models are withdrawn from the sand, will be found in the Repertory of Arts, vol. xiii. p. 8.

In the Philosophical Magazine for 1829, there appeared an article on the adhesion of screw-nails, by B. Bevan, esq., civil engineer. The screws used in the experiments of this gentleman were about two inches long, $\frac{22}{100}$ diameter of the exterior of the thread, $\frac{15}{100}$ diameter at the bottom, the depth of the work or thread being $\frac{35}{1000}$, and the number of threads in one inch 12. They were passed through pieces of wood exactly half an inch in thickness, and drawn out by the weights given in the following table : —

	lbs.		lbs.
Dry beech - -	460	Dry mahogany -	770
" - -	790	Dry elm - - -	655
Dry sound ash -	790	Dry sycamore - -	830
Dry oak - -	760		

The force required to draw similar screws out of deal and the softer sorts of wood in general, is about half the above.

The occasional delay and confusion arising, when machinery is out of repair, from the difficulty of obtaining nuts and screws of a uniform size, led Mr. Whitworth in 1841 to propose a uniform system in the dimensions and fitting of machinery and in the sizes and arrangements of screw threads. This system has obtained great extension; standard forms and standard gauges have been adopted, by the use of which corresponding parts of machines may be prepared separately with sufficient accuracy to fit without trial.

Notwithstanding the variety of articles which have been described in the preceding pages, as manufactured from wrought and cast iron, it must not be supposed that anything approaching to a description of iron manufacture in general has been arrived at. The outline only of a few of the more striking objects has been dealt with. From the vast extension of the application of machinery, both cast and wrought iron have found many new and important uses. It would be useless within the limits of these volumes to attempt a description of the works now carried on at our large founderies for steam-engines of various kinds. In Cornwall some extraordinary work in the way of castings, as cylinders for the large pumping engines employed for draining the mines, and particularly those used in the draining of the Lake of Haarlem, have within a few years been executed. In the founderies of the celebrated manufacturers of marine and of locomotive steam-engines, works in iron, remarkable alike for their strength, gigantic character, and exquisite beauty of execution have been produced. To these we can do no more than refer, directing our readers who may desire further information on these particular points, to those works of Dr. Lardner which treat especially of the steam-engine.

The extension of railroads over the globe has naturally led to the employment of enormous quantities of the metal whose history has been attempted. It will not, therefore, be uninteresting to examine the present condition of railroads at home and abroad, and endeavour to determine as nearly as we can from existing information the present state and probable progress of iron roads.

At the end of 1852 there was more than 6000 miles of railway laid down, and open for public traffic, in England and Wales, more than 1500 miles in Scotland, and nearly 1000 miles in Ireland; making altogether in the United Kingdom about 9000 miles of railway completed. We are indebted to Dr. Lardner for the following table showing the extent of railways under traffic and the amount of capital invested in them in the several countries in which railways have been constructed (1851.)

	Miles of Railway completed.	Cost of Construction and Equipment.
United Kingdom - -	7,000	250,000,000
Germanic States - -	5,342	66,775,000
United States - -	10,289	66,654,000
France - - - -	1,818	48,781,000
Belgium - - -	532	9,576,000
Russia - - - -	200	3,000,000
Italy - - - -	170	3.000,000
Totals - - -	25,351	447,786,000

Since this table was compiled, a considerable extension of railroads has taken place both at home and abroad. Not merely are Europe and America vying with each other in affording the facilities for transport which railroads offer, but we find the iron-rail in progress of extension across the sands of Africa, and it spans the hills and valleys of our East Indian possessions.

CHAP. XIII.

STEEL.

GENERAL NOTICES. — OPINIONS OF ARISTOTLE AND PLINY. — IMPORTATION AND MARKS OF FOREIGN STEEL IRONS. — CONVERTING OF STEEL. — GERMAN OR SHEAR STEEL. — CAST STEEL. — TILTING AND ROLLING OF STEEL. — REMARKS ON THE IMPORTANCE OF GOOD STEEL. — EXPORTATION OF UNWROUGHT STEEL.

The general history of the knowledge of iron and steel in the earlier ages of the world, and the introduction of these essential articles into the arts, conveniences, and (unhappily) into the dissensions of mankind, has already been succinctly sketched. Some account has been given of the appropriation of those metals, especially in connection with the vast field occupied in this country by the foundery trades. It will, therefore, be the design of this chapter, after noticing some early opinions on the subject, to exhibit somewhat in detail the processes employed in the conversion of iron into steel.

Whether the ancients were in possession of any species of metal so hard as our steel, or what was their method of hardening the bronzes with which we are acquainted, are questions which the investigations of science and history have yet to answer satisfactorily. Those stupendous monuments of antiquity, the Egyptian obelisks, are of porphyry, and, as every one knows, most curiously carved with a vast number of figures. That these sculptures have been executed with some kind of metal tools, and the application of immense labour, of course will not be disputed; they must therefore have been in the possession of metal tools [illegible] would be capable of cutting stones of such extreme hardness. Hence it was the common notion, two centuries back, that the art of steeling tools in the highest degree of perfection was certainly lost to the moderns.

Without pretending to deny the conclusions to which the philosophers of the seventeenth century have come on this subject, it may be mentioned as remarkable, that the ancients, who have written on most subjects, and on steel among the rest, have left us no intelligible information on this point, nor any hints whereby we can infer that they were in possession of any secret in the method of manufacturing chisels or picks, whatever they may have possessed of peculiarity or perseverance in the use of them. This is the more surprising, inasmuch as not only the monuments of Egypt were of the most obdurate material, but likewise the obelisks of Rome are, to a large amount, either of porphyry or red granite, and must, therefore, have required no inferior tools and industry in their execution. In the second place, we do not, in our day, now that the manufacture of steel is so well understood and so successfully conducted, hear any thing of materials too hard to be cut by it, did there exist any competent inducement either in the recommendation of the metal or in the applicability of the stone to try the experiment. The fact appears to have been, that, two hundred years ago, the art of steel making was little known, and less practised, in this country; and of the article imported much was bad, and the methods of making it were often involved in wilful mystery, on purpose to mislead native adventurers. It must, too, be admitted, that the metallurgy of the age had not sufficiently thrown off the credulity of the alchymists to be willing, at once and without trial, to disbelieve the efficacy of certain prescriptions for perfecting the unscientific processes of steel making. "As for the moderns," says Dr. Lister, in the year 1693, "there is great abuse in this manufacture, and the processes now used by most nations are fraudulent, and a poisoning of iron, by certain mineral salts, rather than a true making of steel."

The foregoing quotation is from a paper read before the Royal Society, and constitutes No. 203. of the original Transactions. In this communication, after having given a passage from Aristotle, to which we shall in another place refer, the good doctor, with infinite simplicity, thus proceeds:—"We shall now give the best account how true steel is made at this day, waiving all fraudulent processes. The manner is thus faithfully described by Agricola, *De Re Metallicâ*, lib. 9. And to confirm its antiquity, this way of making steel is, by Kircher, said to be now in use in the island of Elba, a place famous from all ages, even from the times of the Romans, for that metal alone, down to our days. 'Make choice of iron that is apt to melt, and yet hard, and may easily be wrought with the hammer; for although iron which is made of vitriolic ore may melt, yet it is soft, or brittle, or eager. Heat a parcel of such iron red-hot, and cut it into small pieces, and then mix it with a sort of stone, which easily melts; then set in the smith's forge or hearth a crucible, or dish of crucible metal, a foot and a half broad, and a foot deep; fill the dish with good charcoal, and compass the dish about with loose stones, to keep in the mixture of stone and pieces of iron. As soon as the coal is thoroughly kindled, and the dish red-hot, give the blast, and let the workman put on, by little and little, all the mixture of iron and stone he designs. When it is melted, let him thrust into the middle of it three or four or more pieces of iron, and boil them therein five or six hours, with a brisk fire; and putting in his rod, let him often stir the melted iron, that the pieces may imbibe the smaller particles of the melted iron, which particles consume and thin the grosser ones of the iron pieces, acting like a ferment to them, and making them tender. Let the workman now take one of the pieces out of the fire, and put it under the great hammer, to be drawn out into bars, and wrought; and then, hot as it is, plunge it into cold water. Thus tempered, let him work it on the anvil, and break it; and, viewing the fragments, let him consider whether it look like iron in any part of it, or be wholly condensed, and turned into steel. Then let the pieces be all wrought into bars, which done, give a fresh blast to the mixture, adding a little fresh matter to it, instead of that which had been drunk up by the pieces of iron, which will refresh and strengthen the remainder, and make still purer the pieces of iron put into the dish; every which piece let him, as soon as it is red-hot, beat into a bar on the anvil, and cast it, hot as it is, into cold water. And thus iron is made into steel, which is much harder and whiter than iron.' "

That the foregoing is an imperfect description of a eal process cannot be doubted; because, not only is the act of steel being produced indisputable in itself, but the materials enumerated, however strangely brought to-ether, are evidently appropriate to the purpose. The earned doctor, pursuing his observations, says, " There s but one place that I know of, which may give us any ght into the enquiry concerning our tools, and that is n Pliny, lib. 34. c. 14., where, speaking of iron, he ays, 'Fornacium maxima differentia est. In iis equidem ucleus ferri excoquitur ad indurandam aciem, alioque modo ad densandas incudes malleorumve rostra.' From his passage it should seem that the ancients had one way o make steel, and another way to harden or temper their ools, particularly such as picks and anvils. It is also lain that 'nucleus ferri' was melted down in both. Again, the difference was in the furnaces, that is, in the manner of ordering the iron to be made into steel, or for he extraordinary hardening of the heads and tips of ools, and not of the matter of which they were made, or both were done by boiling them in molten iron. It annot be doubted but by 'nucleus ferri' must be meant ell-purged iron; the same which Aristotle calls *ειργασενος σιδηρος*; for why else should he tell us that wrought-on itself may be made liquid, so as to harden again, hat is, to cast again into sow-metal, if it was not to explain to us the manner of making steel: which they did, probably, after the precept above delivered; that is, not only to boil the iron in its own sow-metal, or liquid iron, but hammer it also, and after that quench it in cold water."

It may perhaps be deemed presumptuous, after the puzzling passage above cited from Pliny has been so long allowed to rest under the foregoing interpretation, to disturb the sense, or rather the unmeaningness put upon it by learned men, by giving a very obvious common-place solution of its seeming ambiguity. But may not Pliny simply mean to tell us, that iron in two states is exceedingly hard—indicating in the first place brittle cast-iron, or white short, and in the other cemented steel? On this hypothesis, instead of putting upon *nucleus ferri* the forced meaning of "well-purged iron," we only require the plain translation "ironstone," and which, in fact, becomes at once elegant and significant, when used in reference to the ore in those nodular masses in which it is often found. That the wootz of India, in the state in which we receive it, is the immediate product of the ore, seems to be undoubted; and yet it is not only in common with all other pig metal derived directly from nucleus ferri, but it has, in common with steel, the properties of malleability at a certain heat, of hardening by immersion when hot in cold water, and of being tempered in the usual manner. It appears equally indubitable that Pliny uses *densare* to denote "cemented" if not cast steel: and certainly no epithet could be more happily descriptive of the change induced upon iron by the carbonating process, at a time when chemical nomenclature was only more imperfect than the science which in modern times has so enriched it.

Dr. Lister, however, must be allowed to have fair play for his opinion in favour of the superior knowledge of the ancients in the management of their instruments. "As to the steeling of their tools, they boiled them in sow-metal to such a degree of hardness or temper as was requisite, and did not afterwards hammer them.

And this seems to be implied in the phrase 'densare;' for, although it be generally said, that iron is purged and refined for the making of steel, yet, according to the last and truest process, the matter is plainly otherwise; for iron this way made into steel becomes a kind of electrum, and is filled with an exceedingly brittle and hard body of its own nature, iron being spongy and not close; for which purpose, therefore, the word 'densare' is by Pliny aptly and elegantly used. And this way was used when the strongest temper and hardness was required, as for picks and anvils; for which there might be several reasons given; as, first, that it is easier to work iron than steel into any figure, that being far softer and more ductile and loose: again, it is certain that iron by ignition is spoiled or corrupted, so that the oftener it is purged, though it were steel, it would the more relent. Whence the ancients, knowing well that in making their tools of steel, they must considerably loosen it and abate of their temper, they therefore first shaped them, and then gave them a strong body of steel and temper together, and so had nothing else to do but to finish them on the grindstone and hone, to set the point or edge." A modern steel-worker would look upon these opinions as highly apocryphal.

Whatever may have been the practices of the ancient iron-workers in reference to the conversion of their material, if conversion it required, or whatever may be the real meaning of the writers quoted, it is passing strange that any individual in England should talk about steeling articles by "boiling them in sow-metal," when the notorious result of such a course, whether the articles were iron or steel, must be precisely similar to what would take place were a pound of candles to be boiled in melted tallow: steel, as is well known, is melted with the greatest facility every day in the converting and refining establishments; and malleable iron, however difficult of fusion *per se*, loses all its obstinacy, and presently runs down in the crucible, by admixture with a small portion of cast metal; it is indeed common enough with a class of casters afterwards mentioned to correct the quality, or supply the deficiency of good pig-metal, by melting therewith any proportion of old iron that they may think desirable. The test of the crucible is not always at hand even with the translator of an ancient writer on metallurgy.

It may be convenient to observe, *ab initio*, that as every description of pig metal may be made into iron of qualities varying from bad to good, in the degrees according to which each sort contains more or less of impurities; so almost every kind of iron may be converted into steel, which if all the processes be properly conducted, will be valuable or otherwise, according to the character of the ore from which it has been originally extracted.

Although the mineral riches of this country are exceedingly abundant, and amongst our metallic products *ironstone*, as already shown, is neither inconsiderable in quantity nor importance; yet it is generally known that the most valuable steel-irons are imported, chiefly from the north of Europe — Prussia, Sweden, and Russia.

However justly, therefore, and highly we may appreciate the subterranean treasures of our own island — and these are really more valuable than gold or silver or precious stones — we are still compelled, in reference to our native varieties of this most useful metal, to reply in the negative to the emphatic question of the prophet Jeremiah, "Shall iron break *northern* iron and steel?" The principal part of the iron trade as to shipping being transacted over the North Sea, geographical situation has made the port of Hull the great entrepôt of importation from the countries above-mentioned: hence the quantity of iron unloaded there from the various vessels is prodigious. Of these immense arrivals part is carried to Newcastle, some to Birmingham, and a still smaller portion to London; by far the largest proportion, however, of the whole amount, more especially of the most valuable kinds, is brought by canal to Sheffield, and there converted into steel.

Like other remarkable commodities which owe their celebrity to, and command a sale from, their connection with a prescriptive approbation, long established, there are certain kinds of foreign iron, the names and marks of which, as being the accredited guarantees of quality, always fetch maximum prices; and, after conversion, are wrought with entire confidence into warranted articles. The *marks*, therefore, which distinguish imported bar-iron are as numerous and as various as the makers or the mines whence they are derived. It would neither be instructive nor amusing to the general reader to give here a complete vocabulary of these symbols, so significant to the practical iron-masters. As a specimen, however, the following, in the order of their celebrity and value, may be mentioned; 1. Ⓛ (hoop L); 2. GL (G L); 3. ⁚ (double bullet); 4. GF (G F); 5. (gridiron); 6. JB (J B); 7. (stein-buck); 8. (C, and crown); 9. CCND (C C N D). The last-mentioned mark indicates the popular iron which is brought from the extensive mines of count Demidoff in Russia, the late noble owner of which was recently shot dead in a duel with a German nobleman, who is said himself to have been pursued and assassinated by Demidoff's servant, soon after the murder of his master. As the reputation of the foregoing and other marks has given them precedency in the market, it has been contended that prejudice as well as superiority might operate in excluding other valuable but unaccredited irons from obtaining a fair trial either in the furnace or on the anvil. Accordingly, several new marks have found their way into good use, though with a reputation vastly inferior to the standard impressions.

Although the integrity of this important *coinage* of the metal is never violated by the makers or the immediate importers, yet nefarious practices in this way are frequently more than suspected among some of the parties through whose hands it afterwards passes. This imposition is effected either by breaking off the marked ends of bars of inferior iron, and re-stamping them with a brand cut to imitate the device of some maker of higher character; or metals of inferior quality are melted with, or substituted for others during an after process, when, as the marks are gone, the credit of the caster is the only guarantee to the purchaser. And as no criterion of decided efficiency can be applied to test the metal in its unwrought state, it too frequently happens that its inferiority or worthlessness are only discovered when too late to be remedied — the respectability of the vender is in general the only security which the user of the material can have against being imposed upon himself, and of being made the unconscious agent in imposing upon others.

By far the most celebrated and valuable of these marks, and the excellency of which, as an article for cast-steel, is unapproached by the other irons, is hoop L. It is the product of the Dannemora mines in Sweden, and owes its superiority to some properties with which we are almost entirely unacquainted: it is not even known whether these properties are to be referred to some peculiarity in the ore, or to some secret in the manufacture — some testimonies affirming that the smelting and forging is the same at all the works; and others, that irons of inferior celebrity are produced from the same Dannemora mines, where, in fact, different masters are said to be in the habit of lending to one another identical ores to be smelted for different sorts of iron. As the Swedish irons are wrought with charcoal, and the supply of wood necessarily limited by nature, so is the amount of iron annually produced limited also by government, and taxed to a trifling amount. This politic course has at once kept up the price and the means of the manufacture against individual cupidity or competition.

The "region of the mines,' so called in Sweden, occupies the whole breadth of the country, from the boundary of Norway to the Gulf of Bothnia, its northern boundary being a line drawn from Glommen, throug

Lake Siljan to Soderham; its southern boundary lying along lat. 59° N. The area of this district is 16,000 square miles. The best iron is obtained from the Dannemore mines in Upsala Lin, of which ore upwards of 3,000 tons is annually received into England, and employed at Sheffield and other places for making steel. The annual produce of all the iron mines of Sweden is about 70,000 tons of bar iron.

The number of furnaces employed in the neighbourhood of Sheffield for the conversion of iron into steel is upwards of 120, each of them capable of converting weekly six tons of iron, and consumes during the process a quantity of coal about equal to the weight of the steel produced. There are, also, about 100 steel melting furnaces, each, on an average, containing ten holes for crucibles. Four tons of good hard coke are required to make one ton of cast steel, and each furnace of ten holes produces 4½ tons of melted steel per week. The annual quantity of steel produced in Sheffield is about 17,000 tons from foreign (Swedish and Russian iron) and from 1500 to 2000 tons from British iron.

The foreign irons when imported are mostly in flat bars, varying it may be in length from seven to fourteen feet, and, of course, differing somewhat in strength also: it is in this state that they are passed through the converting furnace.

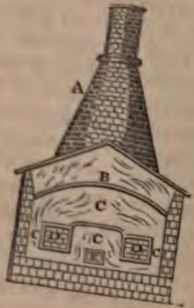
The furnace, in which the process of conversion is effected, is exteriorly a sort of bottle-shaped building of brick, resembling an ordinary glass-house; it is, in fact, the conical covering of a large oven seven or eight yards wide at the base. Under this cupola the furnace is constructed; it consists of two oblong receptacles or troughs, about fourteen feet long, two or three feet deep, and about the same in width, and composed of the best fire-stone, four or five inches thick. These coffers, or *pots*, as they are called, are placed in parallel directions, a little space from each other, and in such a manner as to admit of being entirely surrounded by the flames and heat of a fire kindled beneath them, the air being admitted through

an aperture in front. In order to confine the
much as possible to the pots, a dome or arch of
with vents on each side for the escape of the sm
thrown over them, at a trifling elevation; so that
the furnace is in work, there is an intense heat ke
within this oven.

A reference to the accompanying sketch will en
the reader more clearly to comprehend the descripti
it exhibits a transverse section of the apparatus,
walling of which is supposed to be partially removed
show the relative situation of the different objects.

A is the outer conical chimney or cupola. B the ar
over the furnace. CCCC fire flues enveloping the pot

Fig. 75.



DD the pots containing the metal. E the aperture by which the fire is supplied, and the draught of air admitted or regulated.

The furnace is always cold when charged with the metal. In the first place, the bottom of the pot or trough is covered to the depth of two or three inches with roughly granulated charcoal of the best quality; upon this as many bars of iron, side by side, are laid as the surface will accommodate; over these a stratum of charcoal, and then another layer of iron; and thus in succession till the last bed reaches nearly to the margin of the receptacle, which contains from thirteen to seventeen tons of metal. The whole is then covered thickly with river sand or earth that will not easily vitrify. In Sheffield, a mass of the stiff ferruginous mud, called *wheelswarf*, the stuff which is produced by the wearing of the grindstones, is generally used. This is to prevent the charcoal from burning away, and confine the action of its carbonaceous quality as much as possible to the iron. Every unnecessary aperture is then carefully closed, and a hard coal fire lighted, which is kept up with a considerable degree of intensity night and day for about a week, a little more or less, according to the degree of carbonisation required. Whenever the interior of the troughs reaches the temperature of about 70° Wedgewood's pyrometer, the carbon begins to be absorbed by the iron. To ascertain how the process is going on, a small hole is usually left in the end of the pot, through which a bar can be drawn. If left too long in the furnace the bars will melt. Mr. Buttery, of the Monkland steel-works, in a communication to Dr. Ure, says, "When the iron has absorbed a quantity of carbon in the blister steel furnace sufficient to constitute steel of a proper degree of hardness, and the heat after this is continued to be kept up, the steel will keep absorbing more and more carbon. The fusibility will continue to increase just in the same proportion, till at last it becomes so fusible, that even the limited heat of a blister steel furnace brings it down; and just at the time it is passing to a fluid state it takes so great a quantity of carbon, as changes it from the state of steel to that of cast-iron. It appears to me, that the charcoal is combined in rich cast-iron in the mechanical state, and not in the chemical, as in steel."

When the metal, by appearances familiar to the workmen, is found to be sufficiently pervaded by the carbon, the furnace is suffered to cool. In the course of about six or seven days, a man enters the pots to remove the contents; the charçoal having been preserved from combustion by the place being kept air-tight, has suffered little alteration in appearance, and is laid aside to be used again: the bars, which were before as smooth as the forge hammer left them, are now covered with large or small blisters, occasioned by the rarefaction of small quantities of air during the process of conversion. In this state the metal is called *blistered* steel.

On breaking the bar, the fracture, which in the iron state was comparatively fine grained, with an intermixture of brilliant facets, is now crystallised as the workmen say, but perhaps may rather be said to be lamellated; its brilliancy is of a grey colour and less glittering than before: it appears as if an entire disruption of the internal structure had taken place. This peculiarity of fracture is of uniform appearance if the carbonising process has been complete; but if only partially effected, the centre of the rod still exhibits its duller iron-like structure, or *pith*, as the workmen term it. It may be remarked, that even with the same sort of iron very different degrees of carbonisation are requisite, as the steel may be for different uses. For razors, the hardest state is essential; for files, it is a degree lower; for tools, somewhat lower still; and for coach-springs, a still inferior degree of the carbonaceous quality is required.

The carbon which the metal has derived during the above described contact with the charcoal, has increased its weight somewhat less than the one hundred and fiftieth part. And it will be evident, that not only may any kind of iron be converted into a description of steel analogous to the primitive quality; but that, as applied to the best material only slightly changed, the term *steel* itself may be said to imply rather a relative than an absolute condition of the metal. It is indeed obvious that the compactness of texture, capability of extreme hardness, and consequent liability to break, which characterise the blade of a lancet, would be ruinous in the material of a coach spring. All steel, however, whatever be its comparative fineness of granulation, possesses absolutely the qualities of becoming hard and brittle, after having been plunged while red hot into cold water or oil; and moreover afterwards of becoming more or less elastic, on being to a given temperature. As a curious fact illus- of the natural excellence of the best Swedish iron, affinity to steel, it may be mentioned, that pieces een sometimes met with, out of which capital and other articles have been fabricated, without its oing the process of cementation at all.

Shear Steel.

ough great quantities of steel are used in the blis- tate, yet it is so surprisingly improved by passing the processes next described, that nearly all the sed in the manufacture of the better sorts of cut- struments is submitted to one or other of these ons.

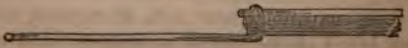
ost every body has heard of the *Damascus* steel; , in fact, little beside the name, and a vague no- at it is made in some parts of the Levant, appears nown about it. Some authors have asserted that s from Golconda in the East Indies, where, add method of tempering with alum, which the Euro- ave hitherto been unable to imitate, was invented. nerally considered that a small quantity of alu- enters into the composition of this steel. It is er asserted, that the real Damascus blades emit a t odour on being bent. Again, it is stated, that he beginning of the fourteenth century, Timur n his conquest of Syria, carried all the celebrated ctures of steel from Damascus into Persia, since period its works in this metal have been little able.

famous sabres of which we have heard so much, were once held in such high estimation through- rope and the East, are said to have been con- l by a method now lost, of welding together e layers, about two or three lines thick, of iron el. They never broke, though bent in the most manner: and Andrew of Ferrara, who has left e to swords of a matchless temper, one of which ated to have carried wrapped about his bonnet, is believed to have possessed the secret of the Damascenes. The elasticity of these far-famed weapons appears not to have been more perfect than their power of edge, to which, according to grave accounts, not merely muscles and bones, but even common iron and steel yielded.

Although the fact of the Damascus steel owing its peculiarities to the interlamination of iron and steel has been sometimes doubted, the method of preparing one description of steel may be thought to be analogous. Half a century or more ago a kind of steel designated, from the country from whence it came, *German steel*, was imported in considerable quantities for particular purposes. The first manufactory of it in this country was at Newcastle, by an individual of the name of Crowley, who was so successful that his name has now become synonymous, in some parts of the world, with this description of steel itself, by whomsoever made. About thirty years since, several forges for the purpose of making this description of metal were erected at Sheffield. This steel being very suitable for making shears, was called *shear steel*, by which name it is generally known. Indeed, so far has the use of this term prevailed, that it is not unfrequently formed into a verb by the workmen, who indicate the process about to be described by the term *shearing*.

For this purpose six or eight pieces of bar-steel, about thirty inches in length, and in its blistered state, are placed upon each other, and the ends of the whole inserted into a stout square hoop, at the extremity of a pole of iron, five or six feet long, in the manner here represented.

Fig. 76.



The fasciculus thus prepared is placed in a wind furnace until the whole mass becomes of a welding heat,—sand being meanwhile frequently scattered over it by means of a small shovel, and which, by forming a flux or glaze, has a tendency to prevent the metal from fusing or burning away. When reduced to a glowing heat, the mass is withdrawn from the fire, and placed under a heavy forge hammer, striking slowly at first, and then quicker, until the whole is drawn into a rod about two inches square; it is then cut in the middle, placed together, and welded again as before; being afterwards reduced to the size required. Steel thus treated not only loses all those seams and flaws so frequent in the blistered bar, as occasioned by the imperfect operation of the foreign forges; but it at the same time acquires a uniformity of quality throughout, as well as a degree of malleability and tenacity which greatly increases its value for many of the purposes to which it is applied. It is called double shear, single shear, or half shear, accordingly as the doubling and welding may have been more or less frequently repeated. The article known among dealers by the appellation of faggot steel, is manufactured by a process analogous to shearing.

A patent was taken out by Mr. Charles Sanderson, of the Park-Gate iron-works near Rotherham, "for a new method of making *shear steel.*" The patentee represents his invention to consist "in forming *shear steel* out of very small pieces of bar steel, instead of pieces from one to two feet in length as heretofore; being thereby enabled to form *shear steel* with fewer heats, and, consequently, with less waste, and without the use of silicious sand as heretofore practised." To this end Mr. Sanderson, in his specification, says, "I take bar-steel, in the state in which it comes from the converting furnace, and break it into very small pieces of one inch to two inches long; a quantity of these pieces being ready, I procure a round stone of any quality which is capable of withstanding a very strong heat without cracking or breaking; and upon this stone the small pieces of steel are piled as closely and compactly as possible: the whole is then enclosed in a fire-clay crucible, and placed in a reverberatory furnace, where it is allowed to remain until the whole mass becomes of a high welding heat; it is then taken from the crucible and placed under a heavy cast-iron hammer, usually called a *metal helve,* and exactly the same as those used in the manufacture of bar iron. This hammer is driven by machinery, and, from the circumstance of the whole mass being in a semi-fluid state, it is almost instantaneously hammered or manufactured into one solid mass or bloom of steel, of from three to four inches square. This bloom is then placed in a furnace, or, as it is more generally termed, *a hollow fire* of two or three feet square, heated with coke, and the heat increased by the application of a blast of air; and the whole mass or body of the steel being raised to a high welding heat, it is then taken from the furnace and placed under the hammer above-mentioned, and drawn into a bar of shear steel, ready to be tilted or rolled into the various shapes or sizes that may be required."

Cast Steel.

About fifty years since a person of the name of Huntsman, residing at Attercliffe near Sheffield, conceived the idea of reducing steel to a fluid. He pursued the experiment with complete success, and was for some time the only noted manufacturer of an article which, bearing his name, is still held in high estimation. His success gave rise to competition, and Mr. Booth of Brush House established extensive and successful works at Rotherham. The refining of steel, however, has decayed at the latter place, in consequence of the amazing extent to which the art is practised and the business carried on in the neighbouring town of Sheffield. The prodigious number of furnaces constantly at work, the number of hands employed, and the amount of steel cast into ingots, to be tilted or rolled for the various purposes to which the material is applied, excite the astonishment of visitors. This town has not only become by far the largest laboratory and emporium in the world for cast-steel, but, in consequence of being the seat of the cutlery and edge-tool trades in general, the facilities for experiment and adaptation on the spot have enabled the Sheffield steel makers to surpass all others in the perfection to which they have carried this important branch of our national industry. It is indeed a remarkable fact, that this very town, which was formerly indebted to Styria for the steel used in its manufactures, now exports a material of its own conversion to the Austrian forges, and other places on the continent of Europe.

Iron, previous to having undergone the process of carbonisation, may rather be said to *burn* than *melt* on exposure to intense heat. When, however, it has been converted into steel, its fusibility at a proper temperature becomes comparatively easy. For this purpose, the blistered bars are broken into small pieces and put into a barrel-shaped crucible of Stourbridge clay, capable of holding from thirty to forty pounds of metal. This pot is then placed, with the assistance of a pair of tongs, in a draught furnace. These furnaces, of which six or eight are generally constructed in a row, and the apertures or mouths of which are level with the floor, are twelve or sixteen inches square, and from two to three feet deep. At the bottom of the furnaces are grates, the air draughts and ash-holes of which are in the cellar; while the outlets for the flame or smoke are on one side near the top, where they immediately open into one common and wide chimney.

The crucible being inserted in the fire, which is fed with the hardest bright coke or cinders, it is covered with a cake of fire-proof clay, and completely imbedded in the fuel; after which a lid of fire-bricks fastened in an iron frame is placed over the furnace to increase the draught, until a sufficient intensity of heat has been produced to melt the metal. Generally in about four hours the liquefaction of the mass is complete: the furnace cover is then removed, and other preparations are made for pouring the metal into cast-iron moulds.

This is a process which exposes the melter to an extremely high temperature; indeed, the eyes and the hands that are daily conversant with molten steel would hardly shrink at the mention of a temperature sufficient to broil a beef-steak! Previously to drawing the crucible, the workman, whose body, arms, and legs are defended by sacking wrappers, goes to a water-trough, and thoroughly moistens his outer covering that his clothes may not get a-flame while he is bending over the mouth of the "burning, fiery furnace." Thus prepared, with a pair of strong tongs he withdraws the pot from the fire, takes off the lid, and pours the metal into the mould. The ingot thus formed is either a bar about two inches square for tilting, or a plate six inches broad, twelve to eighteen inches long, and an inch thick, for rolling, as the same may be wanted to be wrought into its ultimate form by the hammer or the shears. It may perhaps be thought that this fluxing and pouring of the metal requires no very great skill in the management; it is, however, a fact, that so much depends upon the most exact attention to a number of minute particulars, only to be attained by a rare union of judgment and experience, that a person who thoroughly understands the business is invaluable as a workman, and his earnings are accordingly great. Honourable instances are not wanting of these melters having become persons of property. The importance of their avocation is indeed much greater than may generally be imagined, even when the best irons are used: not only does the perfection of innumerable exquisite cutting instruments depend almost entirely upon the quality of the metal, but much of the glory of the fine arts. The steel plates, which, by a wonderful triumph of skill, the engraver has appropriated, the burin of Heath, and the chisel of Chantrey, respectively owe their excellence to a judicious management of the crucible by the Sheffield cast-steel melter.

Nearly every kind of steel requires a particular degree of heat to impart to it the greatest hardness of which it is susceptible. If heated, and suddenly cooled below that degree, it becomes as soft as iron; if heated beyond that degree, it becomes very hard, though brittle, and its brittleness is an indication of the degree of its heat when cooled off. These are the reasons why, in hardening steel, we generally over-heat, and then temper it. Steel loses carbon when over-heated; therefore, in hardening it, the utmost attention must be paid to every stage of the process, if we desire to preserve its quality. The higher the heat at which it was manufactured, the greater the degree of heat it will bear in hardening and welding. For this reason, cast-steel will not bear so high a heat as other steel. German steel is produced by a higher heat than blistered steel, and the latter by a higher heat than cast-steel.

The quantity of carbon necessary to render iron steely, is in a measure dependent on the purity of the metal itself, as, when it contains a small proportion of sulphur or phosphorus, it is rendered much more hard and brittle by a given amount of carbon, than when the same proportion is combined with a purer description of metal. Shear steel of the best quality contains from 1 to 1·5 per cent. of carbon. When steel contains a more considerable amount of this substance, it becomes harder, less tenacious, and more difficult to weld; and when the quantity of carbon present exceeds 1·75 in 180 parts, it no longer admits of being welded at any temperature. The following is the composition of several varieties of steel: —

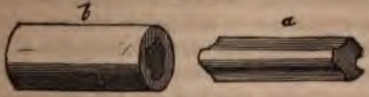
	English Cast-Steel.	Razor Steel.	Siegen Steel.	Styrian Steel.
Iron	97·94	93·80	97·88	98·06
Carbon	1·72	1·43	1·70	1·94
Sulphur		1·00	trace	trace
Silicon	0·22	0·52	0·04	trace
Copper	0·07		0·38	trace
Arsenic	0·07	0·93		
Manganese	0·02	1·92		
Antimony		0·12		

The admixtures depend, of course, upon the constitution of the ore. Russian iron ore, for example, frequently contains sulphur, silex, titanic acid, and copper. The Dannemora ore contains some manganese, copper, sulphur, silex, and often a small amount of lime and clay. English cast-iron is found to contain, besides carbon—manganese, cobalt, chromium, calcium, sodium, potassium, sulphur, and phosphorus.

Tilting and Rolling.

Sheet steel for the manufacture of saws, and for various other purposes, as well as steel in the state of bars, is flatted or elongated by being repeatedly passed when red-hot between large metal rollers, either plain or grooved, and driven by water or steam power. These rollers differ in no respect from those generally employed in the reduction of rod and plate iron. They are in both cases usually made of cast-iron *chilled* on the outside to make them hard, and afterwards turned in an engine with great labour to make them true and smooth. As it is often required during the reduction of a bar of large dimensions to a small size, whether round or flat, that the uppermost roller shall be allowed a considerable degree of play or freedom, in order that it may rise from the lower one to a sufficient height, its connection with the moving power (which is now generally communicated at the opposite end to that at which it is given to the lower roller) is maintained by a coupling bar and boxes. This contrivance, which is well known among millwrights, consists of a solid piece of iron, *a* (*fig.* 77.), having throughout its length, at equal distances, three deep semicircular grooves, similar in all respects to a like number of grooves of the same depth, on the tenon or projecting axis of the roller; *b* is an oblong cylindrical box of iron, cast with three channels inside, exactly answering to the outside size and form of the bar and axis above described. When two of these boxes are placed, one upon the projecting part of the roller and the other upon the axis of the connecting cog-wheel, with the

Fig. 77.



corresponding bar between them, instead of fitting tightly into each other they play loosely together, so that when the upper roller rises considerably, the bar and boxes rise with it at that end; and although sometimes thrown a good deal out of the horizontal line, they still efficiently maintain the connection between the upper and lower rollers, by means of the cog-wheels at the extremity.

To counteract the jolting which takes place by the falling of the upper roller against the ribs or the surface of the lower one, when a thick bar has just passed through, a coiled steel spring has been inserted in a cavity of the cast-iron puppets, and which, by bearing up a metal collar upon which the axis of the roller rests, prevents all that noisy and injurious collision which must otherwise take place. As a proof of the utility of the heliacal spring just mentioned, we were shown by the ingenious workman who applied it in the extensive works of the Messrs. Sanderson, a pair of rollers about three feet in length, and divided into eighteen or twenty semicircular grooves, diminishing from two and three quarters to five eighths of an inch in diameter at the section, and consequently with but narrow intervals or prominences, working against one another, which rollers had been in constant use upwards of six years without having sustained the least injury, or even being reduced more than about one sixteenth of an inch in diameter.

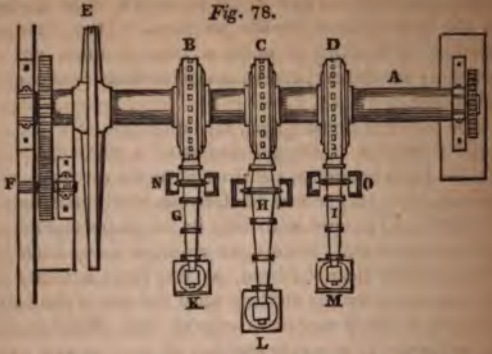
Steel, as well as iron, is passed between the rollers, either as bars or sheets, while at a red heat. It is brought into this state by being placed on a bed of glowing cokes in a brick oven or air furnace, the fire of which is supplied with coals by a door at the further end, by which means, as the chimney is in front, and a low wall across the middle, the blaze is made to pass rather *over* than *upon* the steel in progress of being heated; the fuel being advanced towards the front of the oven, as the bituminous grossness is sufficiently thrown off in flame and smoke. When the bar is glowing hot it is drawn forth with tongs, the workmen tossing it in this state from one to another, catching and manipulating it under the rollers with amazing dexterity. During the operation of rolling, large flakes, sometimes the size of one's hand, fall abundantly from the surface of the metal. This profuse oxydation takes place in the working of iron or steel in a state of ignition, whether by the rollers or the hammer: in making shear steel, it sometimes amounts to a wastage of one sixth of the original weight.

It may be observed, that the more steel is rolled, and especially the greater degree of pressure that is laid upon it as it becomes cooled, in the same ratio does it approximate in closeness of texture and practical value to that which has been drawn out under the hammer; the latter, indeed, being often worked with considerably less of uniformity both in the heating, the beating, and the extending, than the former. In order to get the bars to the exact size required, the workman has a gauge which he applies to measure the width and thickness of bars, and the strength of plates; and such is the nicety of perception acquired by an eye daily conversant with such matters, that he rarely fails to hit the required size with the utmost precision. More than one patent has been obtained for methods of rolling steel for coach and carriage springs: that of Mr. Thompson, a metropolitan steel-maker, was for the fabrication of taper bars, wedge or double-wedge plates of steel, by means of rollers instead of hammering. His plan consisted in having the periphery of the operating cylinder so elevated, and lowered at given distances, as to reduce the metal at the ends, and leave it thicker in the middle of the lengths, according to circumstances.

All steel, whether cast or shear, which is to be used for the best articles, should be *tilted* to the strength required, by working it under a large hammer put in motion by machinery, and which gives about 300 strokes per minute.

The annexed figure (*fig.* 78.) is the plan of a tilt, reduced from the working drawing of a millwright: it exhibits three hammers, the two shorter for cast steel, and the middle or longer one for German steel; the helves are stout ash, hooped with iron in the same manner as the forge hammer. Instead, however, of being lifted by arms or cams near the head, as the forge hammer is, they are raised by the striking upon the tail of the helve of what are called tappits or cogs of iron, placed on the circumference of a ponderous box of wood or cast iron, revolving on the tilt shaft, and the motion of which is equalised by carrying a fly-wheel, additional to the fly-wheel on the crank axle connected with the moving power, steam, in this instance. Instead of an elastic rabbet or spring pole to give a rebound to the hammer, as in the forge, there is placed exactly under the tail of the tilt hammer shaft, a cast iron anvil in an immense block of wood, the latter buried almost to the ground level. As the wheel shaft revolves, the tappits successively strike the hammer tail, which, as the head rises, comes smartly in contact with the iron block, producing a sudden rebound; so that the strokes are not only repeated with the rapidity already mentioned, but so that the hammer face shall have done execution upon the heated bar before each succeeding tappit begins to operate. The whole fabric of the machinery is constructed in the most substantial manner, and its foundations buried deep in the ground. The anvils under the hammer head are set in large blocks of cast iron, solidly supported; and the cheeks, in which the hammer trunions r pivots work, are either of cast iron or massy oak, nd formed downwards somewhat after the manner of he king-posts on a roof beam, and sunk six or eight

Fig. 78.



feet amidst strong masonry in the earth. In the engraving, A is the shaft, upon which are the tappit wheels B C D, and the fly wheel E; its motion is derived from a cog-connection with the axle F, which likewise carries a fly wheel, and contains the crank of the prime mover. G H I are the hammers; K L M the anvil blocks; and the tops of the pivot-bearers are indicated between N and O.

The fire is urged by blowing apparatus attached to some part of the machinery.

During the operation of hammering, so important in closing the pores of the steel, and thus rendering it exquisitely dense and compact, the tilter sits on a seat reaching nearly to the ground, and suspended from the roof of the building: by this contrivance, and by paddling with his feet, he advances to and recedes from the anvil, upon which he manages the iron under the hammer with singular dexterity.

As might be expected in a material of such universal demand as steel, an article the quality of which constitutes almost the sole criterion of value, not only have patents been obtained for various deviations from the usual routine of manufacture, but most of the cementers and melters affect more or less mystery in their methods of conducting the respective processes. Hence the prohibitive words, "No admittance but on business," are generally interposed between the indiscriminate admission of strangers and the rooms where these important metallurgic operations are carried on.

The most extensive and celebrated works in the world for converting, casting, and preparing steel by tilting, rolling, &c., are those of the brothers Sanderson at Sheffield. To these interesting works, the writer of this volume, on making the proper application, was allowed the most prompt and free access, and this too under circumstances which might well have justified a refusal on the part of the proprietors, had they been influenced by a narrower or less independent spirit. One of these gentlemen, who kindly accompanied the visitor through the works, made a remark which deserves to be noted, not less for its candour than for its truth. To the observation that some persons affected secrecy in their operations, it was replied, "The great secret is to have the courage to be honest—a spirit to purchase the best material, and the means and disposition to do justice to it in the manufacture."

How important it is that the purchasers of an article of such prime importance in commerce and the arts should have confidence in the dealer, where they can have but so few means of judging for themselves, must be sufficiently apparent from the following considerations:—Unlike most other commodities, steel presents but very slender criteria by which to judge of its quality, and the best judges are therefore not unfrequently deceived. To distinguish between hard and kind steel, that is, between steel that has been more or less carbonated, requires no talent, and but little experience: but if the iron mark which denotes its quality be defaced or wanting, the most experienced converter would find it extremely difficult and hazardous to pronounce on its capabilities.

The difficulty is still greater with those who know less of steel manufactures; and if manufacturers themselves are not influenced by the most enlightened policy, they may, and but too frequently do, impose upon the distant purchaser in a manner as disgraceful to the one party as it is vexatious and injurious to the other. Too often the consumer of steel is not only deceived and disappointed in having purchased an article which is utterly worthless, but he perhaps does not discover the fraud till it has involved him in extensive and serious losses; and sometimes he makes the discovery in an impaired reputation as a manufacturer. Even when he escapes the last evil, he is sometimes grievously injured by this want of honesty in the party with whom he deals. Steel is not unfrequently moulded into articles requiring great skill and labour, and defects are seldom discovered till the processes of manufacture are in part gone through, and, therefore, not soon enough to prevent a serious loss. By receiving a counterfeit coin, the man of principle is defrauded of a sum equal to the nominal value of such coin, and no more; but there are cases where an individual, by purchasing spurious steel to the amount of half-a-crown, incurs a loss of 20*l.* and upwards.

But the inconvenience and loss attending bad steel are not confined to the consumer of the raw material—the ultimate purchaser of the article into which it has been wrought is a sufferer. Should the reader happen to be a traveller, he need not be reminded (unless he have been more fortunate than most travellers) of the misery attending a case of bad razors, under circumstances that might render it impossible to help himself to better, or obtain assistance from others. The poor man and the artisan could tell of cruel disappointment suffered when the saw or the axe, the chisel or the file, purchased out of an abridgment of daily comforts, has proved good for nothing—and worse, for it has not only robbed him of past enjoyments, but becomes an impediment to his daily toil.

While on this subject, it may not be amiss to notice an error into which a majority of hardware manufacturers fall, and which is largely prejudicial to this branch of our national industry. The test required by these persons is not, that the instrument, when finished, shall perform to the satisfaction of the final purchaser, but that it fail not while passing through the various stages of workmanship. Now, it may happen, in a few rare instances, that the manufacturing process may be severer than any to which the article will afterwards be subjected, and it is worthy of remark, that in such cases no complaints are heard of bad steel.

In a vast majority of cases, however, this process is neither so severe as the test which the article undergoes in the using of it, nor is it at all analogous. The writer has had an opportunity of ascertaining that cast steel, made from inferior blister steel, would, if not too much carbonated, mould into a razor blade, which might be ground and polished to the satisfaction of the manufacturer; but when the said razor came to be applied to the beard, it worked well two or three times, and then lost its edge altogether; while a razor made from (L) cast steel, though no better to the eye, proved all but infinitely superior to it.

This error is still more palpable and injurious in the manufacture of steel springs for carriages. As coach-springs frequently break, and in the breaking always endanger and often destroy human life, it is surely of the first importance that they should be made of the very best material which the ingenuity of man can discover. So far, however, from this being the case, the very worst steel that is made is wrought into coach-springs. Hence the frequent and fatal accidents that occur, and all because the process of spring-making is simple, and requires not good steel for the purpose.

It is not intended for a moment to be meant by these remarks, that there is not a great difference between good and bad steel in the working; such an inference would be equally opposed to philosophy and fact: the difference is indeed well known to every workman. But it is no less correct that there are many degrees of excellence in good steel, not at all distinguishable at the hearth, in the grinding wheel, or upon the whetstone.

A good deal has been said, on both sides of the question, as to whether or not this country acts with sound policy in allowing the exportation of unmanufactured steel. Persons who take the negative side must assume, either that Great Britain alone can conveniently obtain and convert the best foreign irons, or that, whoever may get the raw material, she can always command the market against the world for the sale of her finished edge tools; both of these assumptions are, in fact, erroneous — it is unnecessary to say to what extent. If, therefore, other countries are content to employ us to make steel for them, and if the connection, certainly not indispensable with either, is, nevertheless, equally advantageous to both parties, the less that a flourishing trade is interfered with the better.

It is certainly doubtful whether, if the legislature were to prohibit or embarrass the exportation of steel, the vigilance of public officers would at all keep pace with the dexterity of the adventurous merchant. In all likelihood it would not. At all events, it would be something worse than ungracious to interfere with the exportation of an article, which other countries may import as well as ourselves, and which we only, as it were, advance one stage towards its ultimate manufacture after receiving it from abroad. It is true there are at present some difficulties in the way of the manufacture of steel in those countries to which it is mainly exported; but those difficulties are not insuperable; and there can be no doubt but that, if our steel were withheld, the parties whom we now supply would soon prepare it for themselves.

It would not be easy to state precisely what quantity of steel has been exported in past years from all the ports of Great Britain, nor is this necessary, in order to show the importance of a trade by which the value of a material is so much enhanced as in the article of steel during its transit through the wonderfully perfect processes of our refineries. In the year 1830, about 900 tons of steel, British and foreign, were shipped in the port of London; but how small a proportion that quantity bears to the whole amount converted for foreign consumption may be inferred from the fact, that one house, during the same year, exported to America nearly twice that weight. The industry called into exercise and the capital kept afloat by this single branch of our national commerce will readily be supposed to be far from small. As already intimated, there is one way in which our home manufacturers may counteract any evils that may eventually arise from the exportation of this invaluable commodity; let them use only the best steel themselves, and then there would not only be but little left for the foreign purchaser, but the comparison between our exported wares and those of the rival manufacturer would be in a very different ratio from what we too often find it at present. It is a lamentable fact in many respects, that the export trade in the best steel has rapidly increased since our own makers of hardware goods have been so eager to substitute low-priced for superior steel irons; for it is well known that, in this as in other branches of commerce, finished goods of inferior quality form the bulk of our exports, while the foreign manufactory is supplied with raw materials of the highest intrinsic value. As an illustration of this point it has been said, that there is probably ten times as much Hoop L sent to America as is consumed in this country, though the amount of steel used at home is at least fifty times greater than the amount sent to the United States.

The exportation of steel to America has steadily increased, and the demand for cutlery, &c. as regularly declined; and at the present moment (1853) the converting furnaces of Sheffield are insufficient to supply the American markets.

CHAPTER XIV.

ALLOYS OF STEEL.

SILVER STEEL. — DAMASCUS STEEL. — PERUVIAN STEEL. — METEORIC STEEL. — EXPERIMENTS OF M. GUYTON. — MESSRS. STODART AND FARADAY. — EXPERIMENTS OF M. BRÉANT. — PROFESSOR CREVELLI'S SWORD BLADES. — INDIAN STEEL. — METEOR STEEL.

Besides the various processes that have been adopted ostensibly with the design of improving the quality of pure steel, an almost equal number of attempts have been made to alloy it with other substances, with which, really or in pretence, it has been found chemically to combine. These projects have given rise to a variety of specious appellations, at the best harmless, when applied to mere superiority in the article professedly manufactured from factitious steel, the real excellence of which, if it have any, the common refiner knows must depend entirely upon his old-fashioned operations skilfully performed. Two eminent chemists make and publish a series of experiments, by which it is demonstrated, that a small portion of various of the precious metals might be mixed, by fusion, with the substance of steel; the idea of turning the discovery to practical account is promptly caught; and *silver steel*, having the advantage of euphony and novelty, becomes a popular denomination in the market. But as there is some chance of this manufacture being considered as new-fangled, and diversity and competition being the body and spirit of business, another projector turns him to antiquity: every one interested in cutlery having heard of the famous oriental sabres that, while they bent like a switch, were of so stern a temper that they would themselves cut through ordinary irons; so, with tolerably good taste at least, we are greeted with the announcement of *Damascus steel*. Silver, however, is an ingredient within the reach of every manufacturer who chooses to put it into his melting pot; and Damascus being a somewhat equivocal epithet, at best applying rather to a mode than a material of steel-making; a third party procures from abroad a few lumps of the celebrated Indian *wootz*, a substance which not many persons have seen, and still fewer thoroughly understand, and under these auspices comes forth *Peruvian steel*. Each of these materials may be of acknowledged goodness and celebrity; but at all events they must alike be content with the common credit of an earthly origin: not so, however, with those ferruginous masses which have, at different times, fallen from the clouds. Poetry and policy unite to favour the notion that iron smelted in ether, and hardened in the north wind, must needs, like Homer's horses begotten of the latter agent, be of excellent temper; accordingly, *meteoric steel* has been among the discoveries which have claimed the approbation of the public. We have taken the liberty to introduce, thus playfully, four denominations of factitious steel, which, when recommended as superior to pure steel, for fine cutlery in general, deserve to be treated in no graver style: as connected, however, with metallurgic phenomena, the processes developing those peculiarities of elementary chemical combination, or mechanical structure, upon which the obvious characteristics of the above named steels are assumed to depend, are far from being uninteresting to the experimentalist.

Attempts to combine iron with silver have at various times been made. The experiments of a French chemist, M. Guyton, as published in the Annales de Chimie, were deemed so satisfactory to the operator, that he concludes his detail in these terms: "Thus the iron was here alloyed with the silver even in greater quantity than the silver with the iron. Iron can, therefore, no longer be said to refuse to mix with silver; it must, on the contrary, be acknowledged that those two metals brought into perfect fusion, contract an actual chemical union; that, whilst cooling, the heaviest, and, at the same time, the most fusible metal, separates for the greatest part; that notwithstanding each of the two metals retains a portion of the other, as is the case in every liquation; that the part which remains is not simply mixed or interlaid, but chemically united; lastly, that the alloy in these proportions possesses peculiar properties, particularly a degree of hardness that may render it extremely useful for various purposes."

A few years ago Messrs. Stodart and Faraday made a series of experiments on the alloys of iron and steel at the laboratory of the Royal Institution, the results of which were subsequently published in the Journal of Arts and Sciences. From the account referred to it appears, that not only silver, but platinum, rhodium, gold, nickel, copper, and even tin, have an affinity for steel sufficiently strong to make them combine *chemically* according to the import of this notice, though only *mechanically* in the opinion of some persons. With respect to the alloy of silver, there are, according to the testimony of the experimentalists mentioned above, some very curious circumstances attending it. If steel and silver be kept in fusion together for a length of time, an alloy is obtained, which appears to be very perfect while the metals are in a fluid state; but on solidifying and cooling, globules of pure silver are expressed from the mass, and appear on the surface of the button. If an alloy of this kind be forged into a bar, and then dissected by the action of dilute sulphuric acid, the silver appears, not in combination with the steel, but in threads throughout the mass, so that the whole has the appearance of a bundle of fibres of silver and steel, as if they had been united by welding. The appearance of these silver fibres is very beautiful; they are sometimes one eighth of an inch in length, and suggest the idea of giving mechanical toughness to steel, where a very perfect edge may not be required.

At other times, when silver and steel have been very long in a state of perfect fusion, the sides of the crucible, and frequently the top also, are covered with a fine and beautiful dew of minute globules of silver; this effect can be produced at pleasure. At first the operators were unsuccessful in detecting, by means of chemical tests, the presence of silver in the metallic button; and considering the steel to be uniformly improved, they were disposed to attribute its excellence to the effect of the silver, or to a quantity too small to be tested. By subsequent experiments, however, they were able to detect the silver, even to less than one part in five hundred.

"In making the silver alloys, the proportion first tried was 1 silver to 160 steel; the resulting buttons were uniformly steel and silver in fibres, the silver being likewise given out in globules during solidifying, and adhering to the surface of the fused button; some of these, when forged, gave out more globules of silver. In this state of mechanical mixture the little bars, when exposed to a moist atmosphere, evidently produced voltaic action; and to this we are disposed to attribute the rapid destruction of the metal by oxydation; no such destructive action taking place when the two metals are chemically combined. These results indicated the necessity of diminishing the quantity of silver, and 1 silver to 200 steel was tried. Here, again, were fibres and globules in abundance; with 1 to 300 the fibres diminished, but still were present; they were detected even when the proportion of 1 to 400 was used. The successful experiment remains to be named. When 1 of silver to 500 steel were properly fused, a very perfect button was produced; no silver appeared on its surface; when forged and dissected by an acid, no fibres were seen, although examined by a high magnifying power. The specimen forged remarkably well, although very hard; it had in every respect the most favourable appearance. By a delicate test every part of the bar gave silver. This alloy is decidedly superior to the very best steel; and this excellence is unquestionably owing to combination with a minute portion of silver. It has been repeatedly made, and always with equal success. Various cutting tools have been made from it of the best quality. This alloy is, perhaps, only inferior to that of steel with rhodium; and it may be procured at a small expense: the value of silver, where the proportion is so small, is not worth naming; it will probably be applied to many important purposes in the arts."

The composition of the material formerly so celebrated as the steel of Damascus has given rise to many investigations, not merely on the point as to whether it was indebted for its appearance and elasticity to welded laminæ of iron and steel, or to some chemical peculiarity, but likewise whether a large proportion of the notions connected with its history and excellence may not have been fabulous. The most general opinion has been, that the variegated surface of oriental sabres results from their being composed of what the French call *étoffé*, or mixed metal; that is to say, a compound of bars or wires of steel, or of iron and steel, welded and wrought together, and twisted in different directions. In 1823, the Repertory of Arts published the translation of a paper, giving the result of a series of experiments undertaken by M. Bréant, examiner-general of the assays at the royal mint in Paris. The French philosopher comes to the conclusion, that, instead of a mere mixture of metals, the oriental damask is, in reality, a cast steel, more charged with carbon than our European steels, and in which, by the effect of cooling, properly managed, a crystallisation is produced of two distinct combinations of iron and carbon.

M. Bréant premises that the law discovered by Berzelius, according to which bodies combine that have any affinity for each other, explains, in a satisfactory manner, the property which characterises the steel of the orientals of becoming variegated at the surface, when, after being polished, it is submitted to the action of very weak acid. "Let us suppose," says the investigator, "that in the preparation of steel sufficient carbon have not entered, the steel formed will only be in proportion to the quantity of combined carbon; the rest will be iron, only mixed. The cooling then taking place slowly, the more fusible particles of steel will tend to unite together, and separate themselves from the portion of iron. This alloy will therefore be capable of developing a damask; but this damask will be white, but slightly marked, and the metal will not be susceptible of great hardness, because it will be mixed with iron.

"If the proportion of carbon be exactly such as it ought to be, in order to convert the whole of the iron into steel, there will be only one sort of combination: but if the carbon is a little in excess, the whole of the iron will be in the first place converted into steel. Afterward the carbon remaining in the crucible will combine in a new proportion with the part of the steel already formed. There will, in this case, be two distinct compounds, namely, pure steel and carburetted steel, or cast iron. These two compounds, at first mixed confusedly, will tend to separate when the liquid matter remains at rest. A crystallisation will then form, in which the particles of the two compounds will arrange themselves, according to their respective affinity or their specific gravity.

"Let a blade made of the steel thus prepared be put into acidulated water, a very apparent damask will be developed, in which the pure steel parts will be black, and those of carburetted steel will remain white, because the acidulated water does not so easily show the carbon of the carburetted steel. The carbon irregularly dispersed in the metal, and forming two distinct combinations, is then that which occasions the damask; and it is obvious, that the slower the cooling the larger the damask veins should be. For this reason it is, perhaps, necessary to avoid melting very considerable masses, or rather it will be requisite to make some modification in the process.

In support of this opinion, I think I should quote Tavernier, who, in his Travels in Persia, has given some information which makes us acquainted with the size of the lumps of steel, which in his time were employed in making the damask blades: 'The steel susceptible of being damasked,' says he, 'comes from the kingdom of Golconda. It is met with in commerce in lumps about the size of a halfpenny cake. They are cut in two, in order to see whether they are of good quality or not, and each half makes the blade of a sabre.' From th account it is evident that the Golconda steel was i buttons, like *wootz*. Tavernier adds, that if, in th hardening of that steel, the methods of Europe wer followed, it would break like glass. Hence it may b inferred that it is very difficult to forge, and so it was observed by Réaumur.

"This philosopher having received from Cairo some specimens of Indian steel, found nobody in Paris able to forge them. On this subject, he declares that it must be the fault of our workmen, for the orientals succeed in working this kind of steel. As carbon has the principal influence, not only upon the damask of the steel, but also on its intrinsic qualities, it is to be feared that Messrs. Stodart and Faraday may have been led into error in their labour, as I have been myself for a long time, and that they may have attributed to metallic alloys effects more particularly due to a greater proportion of carbon. I am, however, very far from contesting the existence of metallic alloys in the oriental sabres, although in the few fragments that I have had occasion to analyse, I have found neither silver, gold, palladium, nor rhodium. It appears to me, nevertheless, very probable that various combinations may have been attempted.

"Plumbago has appeared to me in some circumstances to soften the steel, which an excess of carbon would render too harsh; at least, I have obtained excellent results with a hundred parts of steel, one of smoke-black, and one of plumbago. But a very remarkable experiment, in regard to the advantage which may be derived from it, in working on a large scale, is, that a hundred parts of soft iron and two of smoke-black, melt as easily as common steel. It must be supposed that the whole of the carbon does not enter into combination. Some of our best blades are the product of this combination. It is evident from this experiment that it is not necessary, in order to obtain very good steel, to begin the operation by cementing iron. The iron may be treated immediately with the smoke-black, and this would greatly diminish the expense of the manufacture.

" A hundred parts of the filings of very grey cast iron, and a hundred parts of similar filings, previously oxydised, have produced a steel of a fine damask, and fit for the manufacture of bright arms. It is remarkable for its elasticity, a valuable quality not possessed by the Indian steel. The more carbon the steel contains, the more difficult it is to forge. Most of the specimens that I have prepared have not been drawn out but at a temperature, the limits of which are very confined. Heated to white-red they crumble under the hammer. At a cherry-red heat they become hard and brittle, and that disposition increases in proportion to the fall in temperature, so that once arrived below cherry-red, if we would remove a portion with a graver or file, they are found to be much harder and more brittle than after they are completely cooled.

" I am convinced by experience, that the orbicular veins, called *ronces* by the workmen, which are seen on the fine oriental blades, are the result of the manner of forging. If we content ourselves with drawing the steel out lengthwise, the veins will be longitudinal. If we extend it equally in all directions, the damask has a crystalline appearance. If we render it wavy in the two directions, there will be shades and gradations, as in the oriental damask. It will not require long trials to be able to produce any variegated design we desire."

In 1842, the " United Service Journal " contained an article, stating that an imitation of the celebrated "Damascus blades," said to be in no respect inferior to the Eastern originals, had been fabricated in the dominions of both Austria and Prussia; and that professor Crevelli, the inventor of that which had been adopted in the imperial army, had been liberal enough to give publicity to the means by which this formidable weapon might be manufactured. His detailed instructions appeared in a small work, published at Milan, and entitled, "Memoria sull' arte di Fabbricare le Sciabole di Damasco;" of which the following epitome, extracted from the "Allgemeine Militar Zeitung," was given in the periodical above named: — "A long, flat piece of malleable steel, of about one inch and a half in breadth, and one eighth in thickness, is to be first bound with iron-wire, at intervals of one third of an inch. The iron and steel to be then incorporated by melting (welding), and repeated additions (10 to 20) of iron wire, made to the first portion, with which they must be firmly amalgamated. This compound material is then to be stretched and divided into shorter lengths, to which, by the usual process of melting (welding), grinding, and tempering, any wished-for form may be given. By filing semicircular grooves into both sides of the blade, and again subjecting it to the hammer, a beautiful roset-shaped Damascus is obtained; the material can also be made to assume any other form. The infusion by which the figures are made visible is the usual one of aquafortis and vinegar. The success of this method, and the excellence of the blades which have been constructed according to these directions, have by various trials been placed beyond all doubt. Professor Crevelli has had several sabre blades prepared under his own instruction at Milan; similar experiments have, by the emperor's commands, been made at the polytechnical institution at Vienna; and, finally, the war-office has empowered Daniel Fischar, manufacturer of arms in that capital, to proceed with the fabrication on a large scale. These blades, which, when made in large quantities are but little dearer than those in common use, have been submitted to the severest tests; among which may be mentioned, cutting off hob-nails, which had been placed in great numbers behind each other; cuts upon a strong iron plate, and many folds of cloth; horizontal blows upon a wooden table; and finally, powerful bending on both sides. An idea of their extraordinary tenacity may be formed from the fact, that out of 210 blades that were examined by a military commission, and each of which was required to bear three cuts against iron, and two against a flat wooden table, not a single one snapped, or had its edge indented. In Prussia this method of preparing sword-blades is stated to have been in practice several years, and to have been attended with equal success; among others, the manufactory of Schrackenberg, at Malapane in Silesia, has been distinguished for the excellence of ts imitation Damascus sword-blades, which are neither n beauty nor durability inferior to those fabricated at Milan."

The manufactures announced to be of *Peruvian* or *In-ian steel* ostensibly assume as the base of their fabric material known in commerce, under the designation of *ootz;* formerly manufactured at Bombay, and market-ble through the East as a metal suited to the production f cutting instruments of a superior quality, but of which metal the *modus operandi* remains but imperfectly nown to European workmen.

In the Philosophical Transactions (vol. xvii.) may be ound an essay by Dr. Pearson, detailing an elaborate eries of experiments and observations connected with one of the earliest scientific investigations of the nature of this substance. These enquiries were undertaken in consequence of Dr. Scott, of Bombay, having commu-nicated to the Royal Society specimens of wootz; and ith a letter, in which the material is described as of steel held in high estimation among the In-Dr. Scott, in requesting that an enquiry might ted into the nature and properties of the substances transmitted to the society, mentioned to the president some of its peculiarities and uses; among others, he stated that wootz "admits of a harder temper than any thing known in that part of India; that it is employed for covering that part of gun-locks which the flint strikes; that it is used for cutting iron on a lathe; for cutting stones; for chisels; for making files; for saws; and for every purpose where excessive hardness is necessary." Dr. Scott proceeds, "This substance cannot bear any thing beyond a very slight red heat, which makes it work very tediously in the hands of smiths; while it has a still greater inconvenience or defect, that of not being capable of being welded with iron or steel; to which, therefore, it is only joined by screws and other contrivances." He also observes, that "when wootz is heated above a slight red heat, part of the mass seems to run, and the whole is lost, as if it consisted of metals of different degrees of fusibility." According to the doctor's testimony, "the working with wootz is so difficult that it is a separate art from that of forging iron;" moreover, he remarks, "the magnetical power, in an imperfect degree, can be communicated to this substance."

The specimens of wootz transmitted to the society by Dr. Scott resembled in their general appearance and character those which have latterly been exhibited in England, and one of which is now before the writer of this article. They were in the shape of round cakes, of about five inches in diameter, and one inch in thickness, each of which weighed upwards of two pounds. The cake had been cut almost through, so as to nearly divide it into two equal parts. It was externally of dull black colour; the surface smooth; the cut part was also smooth, and, excepting a few pinny places and small holes, the texture appeared to be uniform. It felt about as heavy as an equal bulk of iron or steel. It was tasteless and inodorous. No indentation could be made upon its surface [illegible] with a heavy hammer nor was it broken [illegible] in the opinion of perator would have fractured a piece of our own teel. Fire was elicited on collision with flint. Although he wootz was not quite refractory under the file, it was nuch harder than common or bar steel not yet hardened, and than Huntsman's cast steel not yet hardened. It seemed to possess the hardness of some kinds of crude iron, but did not effectually resist the file like highly tempered steel, and many sorts of crude iron; for though the teeth of the file were rapidly worn down and broken, the wootz was also reduced to the state of filings. The filed surface was of a bright bluish colour, shining like hardened steel; but some parts were brighter than others, indicating inequality of composition; the more shining places seemed to be the hardest parts: hence, perhaps, the reason of the surface being uneven and a little pinny. The wootz filings were attracted by the magnet like common iron filings.

A cake of this substance being broken in the part nearly cut through, the fracture exhibited the grain and colour of rather open-grained steel, but it was not nearly so open as the grain of a bar of cemented or blistered steel in general appears. In the experiments alluded to, the specific gravity of wootz was found to be in a crude specimen 7·181; ditto forged, 7·647; ditto which had been melted, 7·200. At the same time, the specific gravity of bar steel from Oeregrund iron was 7·313; of a bar of German steel, said to be directly from the ore, 7·500 and of Huntsman's steel hammered, 7·916. Common hammered iron was 7·600, and a specimen of cast or brittle iron, which had been re-melted, 7·012.

On submitting the wootz to the effects of fire, it was not until the substance was made red-hot that any considerable impression could be made upon it with a hammer; nor could it be cut through with a chisel till it was ignited to a pale red colour. It had then the peculiar smell of iron; and was stubbornly malleable, and much more liable to be cracked and fractured by the [illegible] than common steel; or, as appeared, than even [illegible] Small and thin pieces were suspected to be malleable at lower degrees of fire, but very slowly, and not without great care and management. An ingenious artist, Mr. Stodart, forged a piece of wootz, at the desire of the president, for a penknife, at the temperature of ignition in the dark. It received the requisite temper, as the operator stated, "at the temperature of 450° of Fahrenheit's scale." The edge was fine, and cut as well as the best steel knife. Notwithstanding the difficulty and labour in forging, Mr. Stodart was from this trial of opinion that wootz was superior for many purposes to any steel commonly used in this country. He thought it would carry a finer, stronger, and more durable edge and point; on which accounts it might be particularly valuable for lancets and other chirurgical instruments.

Although experience has shown that wootz may be manufactured with care by the usual processes into almost all kinds of cutlery instruments, there does not yet exist any evidence in favour of its superiority, or even equality to the best cast steel. Modern workmen have verified most of the results given by Dr. Pearson, especially that of a disposition to fracture which has been largely manifested, when, as has generally been the case, this material has been attempted to be forged into razor blades. The writer of this paragraph was favoured with a piece of the wootz by a gentleman who had it from Bombay: it had already been reduced into the state of a bar, and was considerably cracked across at short distances throughout its entire length. When put into the hands of one of the most expert penknife blade-forgers in the trade, he declared at once that it had been abused by over-heating, and, as if judging by the *esprit de corps*, said that "he thought the workman, finding it hard stuff to work, and bad into the bargain, had spoiled it on purpose, that it might not find its way into use!" Although admonished not to heat it too hot, the penknife-forger said he should like to heat it as he did his steel, in a regular way. This he did; and although the wootz was not quite sound, and did not work freely to a point, it stood moulding with the hammer into a blade pretty fairly on the whole. It was hardened and tempered in the regular way. The fracture of the bit from which it had been drawn resembled that of the best cast steel. The grinder said, that it wore away upon the stone much faster than steel; and that it was not of a uniform degree of hardness throughout. This latter opinion was corroborated by the hafter, who remarked that the tang could be filed with more ease in some places than in others: he used the technical term already quoted from Dr. Pearson, observing, that it was *pinny*. It received a very high polish, and when carefully whetted was found to cut a hard quill very satisfactorily. It was sent to Dr. Lardner, not as being superior to a cast-steel penknife, but as a specimen of the quality and appearance of wootz when wrought and polished with extraordinary care.

It is thus evident that, with peculiar care and patience, pure wootz may be wrought on the anvil into the more delicate kinds of cutlery: at the same time, its fusibility being ascertained, and its general agreement in character with the specific qualities of iron and steel demonstrated by the experiments of Dr. Pearson, the possibility of its entering (with whatever advantages) into the composition of steel while in a state of fusion cannot be doubted; though, according to the account before referred to, the chemical admixture of these bodies, apparently so homogeneous, does not always take place with facility. For, in one experiment, the ingenious operator says, "Equal weights, namely, 500 grains of wootz, steel wire, and grey pig iron were exposed, for half an hour, in the same crucible, well covered, to a pretty considerable fire. On cooling, the pig iron was found to have fused, but the other two states of iron had retained their form. The pyrometer was contracted to near the 140th degree."

The method adopted at the present time, by the natives of India, is, in all probability, from its simple character, similar to that employed in the days of Alexander the Great.

From the Himalayas to Cape Comorin the process is the same, and, though the quantity of metal obtained falls very far short of that which the beautiful iron ores of the country contain, still it is of that fine and uniform quality which has always distinguished wootz.

The furnace or bloomery in which the ore is smelted is from four to five feet high: it is somewhat pear-shaped, being about two feet wide at the bottom and one foot at the top. It is built entirely of clay, so that two men may finish its erection in a few hours, and, exposed to the heat of an Indian sun, it is ready for use the next day. There is an opening in front about a foot or more in height, which is built up with clay at the commencement, and broken down at the end of each smelting operation. The bellows is usually made of a goat's skin which has been stripped from the animal without ripping open the part covering the belly; the apertures on the legs are tied up, and a nozzle of bamboo is fastened to the opening formed by the neck. The orifice of the tail is enlarged, and distended by two slips of bamboo. These are grasped in the hand and kept close together in making the stroke for the blast: in the returning stroke they are separated to admit the air. By working a bellows of this kind, with each hand making alternate strokes, a tolerably uniform blast is produced. The bamboo nozzles of the bellows are inserted into tubes of clay, which pass into the furnace at the bottom corners of the temporary wall in front. The furnace is filled with charcoal, and a lighted coal being introduced before the nozzles, the mass in the interior is soon kindled. As soon as this is accomplished, a small portion of the ore, previously moistened with water to prevent it from running through the charcoal, but without any flux whatever, is laid on the top of the coals, and covered with charcoal to fill up the furnace. In this manner ore and fuel are supplied, and the bellows are urged for three or four hours. When the process is stopped and the temporary wall in front broken down, the bloom is removed with a pair of tongs from the bottom of the furnace.

In converting the iron into steel, the natives cut it into pieces, to enable it to pack the better in the crucible, which is formed of refractory clay, mixed with a large quantity of charred husk of rice. It is seldom charged with more than a pound of iron, which is put in with a proper weight of dried wood (the *Cassia auriculata*) chopped small, and the mass is covered with a few dried leaves of the *Convolvulus laurifolius*, the proportions being in general ten parts of iron to one of wood and leaves. The mouth of the crucible is then stopped with a handful of tempered clay, rammed in very closely to exclude the air. As soon as the clay covers of the crucibles are dry, from twenty to twenty-four of them are built up in the form of an arch in a small blast furnace; they are kept covered with charcoal to be subjected to heat urged by blast for about three hours, when the process is considered to be complete. The crucibles being now taken out of the furnace and allowed to cool are broken, and the steel (wootz) is found in the form of a cake, rounded by the bottom of the crucible.

In the Repertory of Arts, vol. iii., there is an account of a process for making *meteor steel*, which is said to resemble in its superficial substance the wavy appearance of the best Damascus blades. Twenty-four parts of zinc, four of purified nickel, and one of silver, are put into a black-lead or other refractory crucible, the surface being covered with charcoal powder, and the cover luted on, and the whole subjected to the heat until it is fused. When melted the mixture is to be poured into cold water, so as to render it brittle, and more easy to pound into small pieces for use.

From the preceding notices of the practicability of producing and working alloys of steel, it will be obvious that we do not by any means doubt the possibility of giving to steel those qualities which are supposed to be indicated by the denominations before recited. And if persons purchase fine cutlery articles under the idea that these terms are representative of some peculiarity, the delusion will be harmless—perhaps advantageous; for if the lancets, penknives, razors, or scissors, which are baptized by certain high-sounding appellations, happen to contain not in their composition a single particle of silver, wootz, or other foreign ingredient mixed with the steel, it is due to truth to observe, that the steel itself is generally of the purest quality, and manufactured with a degree of care and success commensurate with the prices and reputation of the wares identified with such distinguishing epithets.

CHAP. XV.

NATURAL STEEL.

NATURAL STEEL. — PECULIARITIES OF ITS COMPOSITION. — MR. MUSHAT'S PATENT. — MR. LUCAS'S PATENT. — MALLEABLE PIG-IRON, OR RUN STEEL. — ITS EXTENSIVE APPLICATION AS A SUBSTITUTE FOR STEEL. — METHOD OF CASTING AND ANNEALING ARTICLES OF THIS METAL.

WHATEVER ideas the chemist or the philosopher may attach to the designation *natural steel*, an English edge-tool maker would reluctantly admit that it meant any thing besides, or, at all events, any thing better than, cast iron. It is certain, however, that some kinds of ore, by proper treatment, may be made to yield an inferior sort of steel, without its passing through the intermediate condition of malleable iron. Some years since, the *Annales de Chimie* contained an article on the nature of steel, particularly on that species obtained directly from fused iron, which is termed *natural steel*. According to the writer of the article alluded to, it had been remarked for several years, that the steel of France, particularly that species termed natural steel, would not bear competition with that of other countries, and that the endeavours of learned Frenchmen had not succeeded in enabling native artists to produce uniformly steel equal in quality to that of Germany. In consequence of this difficulty, the writer states that the celebrated manufactory of arms at Klingenthal supplied that at Versailles with what were termed Damascus blades; for the contractors being unable to find good natural steel in France, were obliged to procure theirs from the founderies of Styria and Nassau-Liegen, where the spathic ores only are employed. Bergmann had already asserted that manganese was contained in the white or spathic iron ores: and the author of the observations in the *Annales de Chimie* states, that, having been enabled to make comparative analyses of the greater part of the iron ores of France, he found that the good quality of the natural steel, independently of the carbon and the known processes for rendering it homogeneous, arose from its possessing a certain quantity of manganese, which, in conjunction with the carbon, constituted the best foreign steel; whilst the French smelters indiscriminately employed, in the manufacture of their steel, iron ores which either do not contain this substance, or do not contain it in the requisite proportions. Hence all that uncertainty in the judgments that had been passed upon the uses of French steel, and the disappointments which manufacturers had met with in the properties of their native steel when compared with that of other countries.

Having stated that the varieties of spathic ores which exist as well in France as in Germany contain from four to six and a half per cent. of metallic manganese, the author proceeds:—"Though I am well persuaded that the natural steel of Germany owes its superior qualities entirely to the spathic ores of iron, which are used in preference for its manufacture, and to the manganese which it contains in the requisite proportion, I think it necessary to adduce in support of this opinion a fact which had not been observed; namely, that in the German founderies, and especially in those situated in the territory of Nassau-Liegen, where very good natural steel is manufactured without difficulty, and where they have in the neighbourhood mines of manganese, they substitute the black oxide of manganese as a flux, when the spathic ores and the fused metal employed for manufacturing the steel do not contain a sufficient quantity of this substance."

From the whole of his experiments and enquiries, he deduces the following conclusions:—

1st, The fused native iron, in order to produce uniformly natural steel equal in quality to that of Germany, ought to be obtained in preference from carbonates of iron which contain the largest proportion of manganese, and this metal ought to be contained in the fused iron intended to be manufactured into steel in the proportion of four and a half to five per cent.

2d, In good natural steel the manganese ought to exist in a proportion twice as large as that of the carbon.

3d, Steel in general, and particularly natural steel, is essentially an alloy of iron and manganese combined with carbon, and this alloy is the natural steel of Germany, most commonly in the following proportions: viz.—

Iron - -	- 97·84
Manganese - -	- 2·16
Carbon - -	- 1·00
	100·00

This kind of steel, formerly common in this country, is now scarcely known even by name to our manufacturers. There is, however, one large manufactory of cast-iron in combination with manganese, the steel from which is said to be of very superior quality.

In 1800, Mr. Mushet, a gentleman of Glasgow, to whom the iron trade is considerably indebted for various experiments in practical metallurgy, obtained a patent for the fusion of malleable iron, or of iron ore, in such a manner as immediately to convert them into cast steel, and at the same time to give it malleability and the property of welding. This object he proposed to obtain by putting into a crucible a convenient quantity of malleable iron in bars or scraps, and along therewith a proper proportion of charcoal dust, pitcoal dust, plumbago, or any substance containing the coaly or the carbonaceous principle. This mixture is placed in a furnace until it is run down or fused by the intensity of the heat, after which it is poured out into bar or ingot moulds, or into moulds for various utensils, when it will be found that such castings will be of steel similar to that produced by the tedious process of cementation. But this saving of time and expense was not by any means the whole of the advantage alleged by the patentee in behalf of his method, "for," says he, "when I meet with iron stones or iron ores sufficiently rich and free from foreign mixtures, I save even the time and expense necessary for the conversion of such ore first into cast or pig iron, and afterwards by a tedious and expensive process, accompanied with a great waste of metal, into bar iron; for such ore, being previously roasted or torrified, may be substituted for the bar iron scraps, and the result will be cast steel, provided the proper quantity of any substance containing carbonaceous matter be used, as for the common and ordinary qualities of cast steel; a much smaller quantity of carbonaceous matter is requisite in the mixture than perhaps would have been suspected before my invention: when charcoal from wood is employed, a seventieth to a ninetieth of the weight of the iron will generally be found sufficient; when the quantity of the carbonaceous matter or principle exceeds one seventieth, and is increased from one sixtieth to one fortieth or more of the weight of the iron, the steel becomes so completely fusible that it may be run into moulds of any shape, and be capable afterwards of being filed and polished. Hence, by casting, may be constructed stoves, grates, kitchen utensils, many kinds of wheels and mill-works, a great variety of small machinery, and many other articles which could not be so made by the processes now in use, and which way of making such articles constitutes a part of my invention. By my process, various kinds of steel, differing as much from each other in their qualities as the various kinds of pig or cast iron differ from each other, can be formed by merely varying the proportion of carbonaceous matter. Cast steel, of the common and ordinary qualities, is so volatile when in fusion, as not to admit of being run into any shape except straight moulds of considerable diameter; but steel of such density as to admit of being cast into any form may be produced by my process, by increasing the quantity of charcoal and fusing the matter, as before directed. When I wish to produce qualities of steel softer than is usually manufactured by the common processes, I find it best to use a small proportion of charcoal, sometimes so little as a two hundredth part of the weight of the iron: steel produced with any proportion of charcoal not exceeding one hundredth part will generally be found to possess every property necessary to its being cast into those shapes which require great elasticity, strength, and solidity; it will also be found generally capable of sustaining a white heat, and of being welded like malleable iron; and, indeed, as the proportion of charcoal or other carbonaceous matter is reduced, the qualities of the steel will be found to approach nearer to those of common malleable iron."

Four years after the enrolment of Mr. Mushat's patent, another was obtained by a Sheffield refiner, of the name of Lucas, and which has led to results of no small consequence to the edgetool, cutlery, and hardware trades in general. The title of the specification announces a method of separating the impurities from crude or cast iron without fusing or melting it, and of rendering the same malleable and proper for the several purposes for which forged or rolled iron was used; and also, by the same method, of improving articles manufactured of cast iron, and thereby rendering cast or crude iron applicable to a variety of new and useful purposes.

The patentee thus describes his processes:—The pig or cast iron, being first made or cast into such form as may be most convenient for the purpose for which it is afterwards intended, is to be put into a steel-converting or other proper furnace, together with a suitable quantity of ironstone, iron ore, some of the metallic oxides, lime, or any combination of these (previously reduced into powder or small pieces), or with any other substance capable of combining with, or absorbing, the carbon of the crude iron. A degree of heat is then to be applied, so intense as to effect an union of the carbon of the cast iron with the substance made use of, and continued so long a time as shall be found necessary to make the cast-iron either partially or perfectly malleable, according to the purposes for which it may be wanted. If it be intended to make the iron perfectly malleable, from one half to two thirds of its weight of ironstone, iron ore, or other substance, will be found necessary; if only partially so, a much less quantity will be sufficient. Five or six days and nights will in general be found sufficient during which to continue the heat, which, towards the close of the process, cannot be too great. Care should be taken that the pieces of cast iron be not of too great thickness, as it would have the effect of lengthening the process. But the proportion of the several substances made use of, and the degree and duration of the heat to be applied, must greatly depend, not only on the nature of those substances, but also on the nature and quality of the pig or cast iron employed, a knowledge of which can be obtained only by experience. The cast iron to be rendered malleable, and the substances to be made use of for that purpose, may be placed in the furnace in alternate layers; and, in order to prevent the ironstone or iron ore from adhering to the iron, a thin layer of sand may be placed between them. For the improvement of articles manufactured of cast iron, the same directions may be observed, except that when the articles are small, a less proportion of the substances producing malleability will be required, and also a less degree and continuation of heat.

There is some ambiguity, involuntary or affected, in the foregoing specification. It is not very clear from the terms whether iron in pigs or small castings be principally meant to be treated. The fact was, however, that the discovery was presently turned to a large practical account; and "the variety of new and useful purposes" to which it might be applied, were soon found to include the casting of all sorts of cutlery articles and edgetools, from the largest to the smallest, with the utmost facility.

From that time to the present moment immense quantities of wares, bearing in the trade the equivocal designation of *run steel*, have been daily cast, and treated on the principle of the fore-mentioned discovery; without, however, the pig metal undergoing any alterative process whatever between the blast-furnace and the melting-pot. The metal commonly used for this purpose is the sort drawn from the rich Cumberland ores, Hæmatites.

The processes of casting and annealing these articles, as we witnessed them on a large scale in a Sheffield casting establishment, were conducted as follows: — Models of the articles being prepared, these are imbedded in a stratum of Mansfield rock sand finely pulverised, and moistened a little to make it cohere; it is detained in shallow boxes, opening longitudinally to admit of the models being removed, by which means their exact impressions are left in the sand. They are generally, when the size allows it, placed in two series, one on each side of a main stem extending down the middle, somewhat like a fern leaf; the articles inclining a little from the right angle, that the metal which is poured down this midrib may with the greater freedom run to the extremities of the lateral branches. When the casting has taken place, by the pouring into the cavity already described a sufficient quantity of molten metal, and when the whole has become sufficiently cooled, the boxes are opened, the *spray*, as the cluster of castings is called, taken out and cleared from the sand, and the articles broken from the midrib with nippers. In this state they are almost as brittle as glass; the grain or fracture appearing very close, somewhat crystalline, and very lightcoloured. The material and mode of casting here alluded to are much used in Birmingham, for bridle bits, stirrups, and a numerous list of other articles, which it is obvious may be so much easier and more cheaply cast than forged. For certain descriptions of forks, common snuffers, &c., this metal is peculiarly adapted. They are annealed, or, in other words, decarbonated in the requisite degree, by being placed upright in small cast-iron tubs, which are filled up either with a powder produced by grinding the native ore, which is a most difficult task, or, more generally, with *smithy slack*, which is the shale produced in the forge or during the rolling or the working of red-hot irons.

After exposure for five days and five nights to th
rate heat of an air furnace or brick oven, article
metal become not merely somewhat soft and malle
so altered that they may be heated, hammered, h
and polished like steel. Such is the malleabilit
material when good and carefully treated, that
seen it drawn out by hammering to the finen
knitting needle; and on taking a bit of it to a
rienced workman, and desiring him to forge i
small blade, he succeeded in the attempt, altho
point rather crumbled; and on hardening and t
it he thought it looked like pretty good steel, u
that it was a piece of what he then called cast i

CHAP. XVI.

FORGING, HARDENING, AND TEMPERING STEEL.

EDGETOOL-FORGER'S SHOP AND TOOLS. — MAKER AND STRIKER. — TABLE-KNIFE BLADES. — OBSERVATIONS ON THE BEST METHOD OF HARDENING CUTTING INSTRUMENTS OF STEEL. — MR. MARTIN'S REMARKS ON MEDICATED WATER AND CHARCOAL HARDENING. — TEMPERING. — MESSRS. NICHOLSON AND STODART'S RECOMMENDATIONS. — CHILL HARDENING.

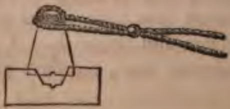
THE shop in which the blade of a cutting instrument is formed from the bar steel by hammering is locally termed a *smithy*, and contains on one side a hearth with bellows, a *stithy* or anvil inserted in a large block of wood or stone according to circumstances, a water-trough for the purpose of hardening, heavy steel-faced hammers, iron tongs, and some other implements of iron and steel. In fabricating the smaller articles, the individual who hammers the steel into the form of a knife blade, for instance, generally employs a boy to manage two or three bars in the fire, and hand them, when sufficiently heated, in succession to the hammerman, who by thus alternately receiving the heated and returning the used rod is kept constantly at work. The uniformity of exertion which is secured by this arrangement, and at the same time the dexterity by which with very simple instruments a material seemingly the most intractable in nature is moulded on the anvil, would astonish a stranger. Indeed long habit and constant practice can alone enable a workman to transform rods of steel into neat blades with the requisite degree of precision and despatch. A penknife blade is formed at two heats; first, the *blade* properly so called;

this is then chopped off the end of the rod, taken up with a pair of tongs, heated again in the fire, and the *tang*, or part by which it is to be held during grinding, and ultimately to be fixed in the haft, is fashioned. The whole is then *smithed*, or smartly hammered after it has ceased to be soft, in order to close the pores, and produce the greatest possible degree of density: having been struck with the nail-mark, and the maker's name or other device from a steel punch, the blade is ready for hardening. The steel springs for the back and iron scales for the inner sides of jointed knives are made by workmen ranking a degree below the blade-makers.

In forming most of the larger articles, such as table knives, files, and edgetools in general, two men are required to manage the forging operation, a *maker* and a *striker*; the former managing *the heat* (as the glowing piece is called), with his left hand, while he uses the hammer with his right; the latter wielding a *heavy* sledge hammer, with which he alternates strokes with the maker. The sounds issuing from the smithies where these double hammers (weighing respectively 3¼ lbs. and 7 lbs.) are at work, is singularly indicative of hard and incessant toil.

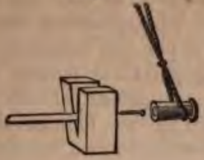
Table-knife blades are composed partly of iron and partly of steel, the two metals being united at the neck or shoulder of the blades. The cutting portion of the blade is first hammered out of a rod of steel, as mentioned above; it is then chopped off, the thicker end inserted in the fire, and along with a rod of iron brought to a welding heat; the two pieces are then laid together, and the tang and bolster formed. The latter object is instantly attained by the assistance of certain implements acting with a boss (*fig.* 79.) and a slit block

Fig. 79.



of iron, called a devil (*fig.* 80.), respectively (of which the annexed are the figures), placed upon the anvil.

Fig. 80.



The handles of these implements are composed of hazel sticks twisted about the heads of the iron punches, and kept together by means of a metal ring.

The blade being properly formed by the hammer, and sometimes, though but rarely, touched up with a file, is next submitted to the routine of hardening and tempering. These processes, though in themselves extremely simple, require the nicest care in their performance, as upon them depends, in fact, almost entirely the main chance of excellency in all edged instruments of steel. It is true, as already observed, if the material be worthless, no care in the treatment of it at this stage can make up the want of goodness of quality; but, on the other side, whatever be the excellence of the metal, if improperly treated in these stages, no subsequent operation can produce the essential properties of a good blade. Steel is commonly *hardened* by being plunged when red hot into cold water; it is afterwards *tempered* by being heated until the surface assume a tinge, varying from a light straw colour to a deep blue, as the article happens to be required for cutting; as a penknife, or for elasticity, as a watch-spring. To obtain a ground for this criterion (which exhibits simply the successive stage of the progress of oxidation), the surface of the metal, previous to tempering, is rubbed bright with a piece of gritstone, or in the finer articles, as springs &c., ground and polished Various chemical accessaries have at different times been proposed to the cutlers; but either from a want of disposition on the part of the workmen, who are mostly compelled by low wages to avoid theories and experiments, and to go the accustomed way to work, or from the want of any superior efficiency in the applications themselves, they are little attended to in practical hardening.

It is a generally prevailing opinion amongst men accustomed to the management of this process, that if steel be over-heated previous to immersion, an extra portion of heat is likewise required to reduce it, or what is termed *let it down*, to a proper degree of hardness, and that without this a good cutting edge cannot possibly be produced. This, indeed, to say the least of it, is a miserable and ineffectual attempt to remedy one error by the introduction of another. That this is an extremely injurious opinion, and that it operates, perhaps, more than any other cause whatever to produce a mass of inferior cutlery, must be obvious to every one who thinks at all upon the subject. It may be laid down as a position which is not in much danger of being controverted, that *the lowest possible heat at which steel becomes hard is indubitably the best;* and that, in fact, to impart to it any extra portion, is essentially to affect its most valuable properties. If over-heated, the pores of steel become open and expanded, the fineness of its texture is annihilated, and it is rendered so extremely susceptible of injury from the influence of heat, that a small portion acting upon it, when it is in this state, entirely destroys its capability of sustaining a cutting edge. It should, therefore, be inferred from these remarks, that no degree of temper whatever will operate to restore to steel the pure properties of which it has been deprived by being over-heated.

The writer of the foregoing and following paragraphs, himself for many years practically acquainted with the various manufactures of steel, has suggested a remedy for the usual defects in these processes; which, however, adds too materially to the cost of workmanship ever to allow of more than its very partial adoption, even in the important article of razors. This intelligent cutler observes, that "articles manufactured of steel for the purposes of cutting are almost without an exception hardened from the anvil; in other words, they are taken from the forger to the hardener without undergoing any intermediate process: such is the accustomed routine; the mischief it occasions has not escaped observation. The act of forging produces a strong scale or coating, which is spread over the whole of the blade; and, to make the evil still more formidable, this scale or coating is unequal in substance, varying in proportion to the degree of heat communicated to the steel in forging; it is sometimes almost impenetrable to the action of water when immersed for the purpose of hardening. Hence it is that different degrees of hardness prevail in nearly every razor manufactured; this is evidently a positive defect; and, so long as it continues to exist, great difference of temperature must exist likewise. Razor-blades not unfrequently exhibit the defect here stated in a very striking manner: what are termed clouds, or parts of unequal polish, derive their origin from this cause; and clearly and distinctly, or rather *distinctly,* though not *clearly*, show how far this partial coating has extended, and where the action of the water has been yielded to, and where resisted. It certainly cannot be matter of astonishment that so few improvements have been made in the hardening of steel, when the evil here complained of so universally obtains, as almost to warrant the supposition that no attempt has ever been made to remove it. The remedy, however, is easy and simple in the extreme, and so evidently efficient in its application, that it cannot but excite surprise, that in the present highly improved state of our manufactures, such a communication should be made as a discovery entirely new.

"Instead, therefore, of the customary mode of hardening the blade from the anvil, let it be passed immediately from the hands of the forgers to the grinder; a slight application of the stone will remove the whole of the scale or coating, and the razor will then be properly prepared to undergo the operation of hardening with advantage. It will be easily ascertained that steel in this state heats in the fire with greater regularity, and that when immersed, the obstacles being removed to the immediate action of the water on the body of the steel, the latter becomes equally hard from one extremity to the other. To this may be added, that *as the lowest possible heat at which steel becomes hard is indubitably the best,* the mode here recommended will be found the only one by which the process of hardening can be effected with a less portion than is or can be required in any other way. These observations are decisive, and will in all probability tend to establish in general use what cannot but be regarded as a very important improvement in the manufacturing of edged steel instruments."

The notion formerly existing that saline and other ingredients much improved the quality of the water to be used in hardening of cutlery is scarcely yet exploded in theory; especially as a mixture is used in the preparation of files and saws. Mr. Martin justly observes, that "no advantage is obtained from the use of salt in water, or cooling that fluid, or from using mercury instead of water; but it may be remarked, that questions respecting the fluid are, properly speaking, applicable only to files, gravers, and such tools as are intended to be left at the extreme of hardness. Yet though Mr. Stodart does not seem to attach much value to peculiarities in the process of hardening, he mentions it as the observation and practice of one of his workmen, that the charcoal fire should be made up with shavings of leather: and upon being asked what good he supposed the leather could do, this workman replied, that he could take upon him to say that he never had a razor crack in the hardening since he had used this method, though it was a very common accident before. It appears, from the consideration of other facts, that this process is likely to prove advantageous. When brittle substances crack in cooling, it always happens from the outside contracting and becoming too small to contain the interior parts. But it is known that hard steel occupies more space than when soft; and it may easily be inferred, that the nearer the steel approaches to the state of iron, the less will be this increase of dimensions. If, then, we suppose a razor, or any other piece of steel, to be heated in an open fire with a current of air passing through it, the external part will, by the loss of carbon, become less steely than before; and when the whole piece comes to be hardened, the inside will be too large for the external part, which will probably crack. But if the piece of steel be wrapped up in the cementing mixture, or if the fire itself contain animal coal, and is put together so as to operate in the manner of that mixture, the external part, instead of being degraded by this heat, will be more carbonated than the internal part; in consequence of which it will be so far from splitting or bursting during its cooling, that it will be acted upon in a contrary direction, tending to render it more dense and solid."

The cracking which so often occurs on the immersion of steel articles in water does not appear to arise so much from any decarbonisation of the surface merely, as from the sudden condensation and contraction of a superficial portion of the metal, while the mass inside remains swelled with the heat, and probably expands for a moment on the outside coming in contact with the water.

Every observant manufacturer of cutting instruments of the finer sorts must have experienced the difficulty of obtaining, in the articles about to be hardened, that uniform degree of heat throughout which is essential to the production of a perfect edge. "This difficulty," says Mr. Nicholson, "formed a very considerable impediment to my success in a course of delicate steel-work in which I was engaged about seven years ago; but after various unsuccessful experiments, I succeeded in removing it by the use of a bath of melted lead, which, for very justifiable reasons, has been kept a secret until now. Pure lead, that is to say, lead containing little or no tin, is ignited to a moderate redness, and then well stirred.

Into this the piece is plunged for a few seconds; that is to say, until when brought near the surface that part does not appear less luminous than the rest. The piece is then speedily stirred about in the bath, suddenly drawn out, and plunged into a large mass of water. In this manner a plate of steel may be hardened so as to be perfectly brittle, and yet continue so sound as to ring like a bell: an effect which I never could produce in any other way." The tempering process may be performed by immersing the articles in the same manner in a bath of molten lead, the temperature of which can be ascertained by means of the thermometer, when it does not exceed the point at which mercury boils.

It is extremely difficult to insure the exact degree of hardness best fitted for the purpose to which a steel instrument is to be applied. The most practical method is to give the steel a very high degree of hardness, and then reduce it to a proper state by the process called tempering. In tempering steel the workman is guided entirely by the colours which appear on the surface of the metal during the operation. These colours are thin films of oxide, which are found to correspond with considerable exactness to the degree of heat to which the metal is exposed.

The following colours will appear in succession on a plate of hardened and polished steel when exposed to a progressive heat. A piece of well-polished hardened steel heated to 430° Fahr., assumes a *faint yellow* colour. This is suited for lancets and other cutting instruments which require an extremely fine edge. At 450° a *faint straw* colour is obtained. This degree of temper fits the steel for razors and amputation knives. At 470° steel acquires a *full yellow* colour, and becomes tougher and fitted for penknives. At 490° the yellow hue becomes *brownish;* and this is the degree of temper best fitted for cold chisels and shears. Steel tempered at 510° Fahr. developes *purple spots* over the brown shade, and is then fit for axes and plane-irons. At 530° it becomes a *purple colour,* and is then used for table-knives; while for swords, watchsprings, &c., a *bright blue colour* is attained at the temperature of 550° Fahr. At 560° the *blue colour* is very brilliant. Steel thus tempered is used for shears and ordinary chisels; and at 600° the metal takes a *dark blue colour,* and is then fit for large saws, &c.

It may not be generally known, that the hardening of steel does not necessarily depend upon the immersion of the metal in liquid of any kind, but may be equally effected by the application of cold. The hardening of cast-iron articles by *chilling* the surface has already been mentioned, and the cutlers are well aware that the same phenomenon occurs in the case of a thin blade, placed when heated between the hammer and anvil faces when both are cold. The *Bulletin Universel* lately contained a notice in reference to the practical application of this principle. From the observation of travellers, that the manufacture of Damascus blades was carried on only during the time when north winds occurred, M. Anozoff made experiments on the hardening of steel instruments by putting them when heated into a powerful current of air, instead of quenching them in water. From the experiments already made, he expects ultimate success. He finds that, for very sharp-edged instruments, this method is much better than the ordinary one; that the colder the air, and the more rapid the stream, the greater is the effect. The effect varies with the thickness of the mass to be hardened. The method will succeed well with case-hardened goods.

CHAP. XVII.

STEEL PLATES FOR ENGRAVING.

MR. DYER'S PATENT FOR PERKINS'S PLATES AND PRESSES. — METHOD OF DECARBONATING THE STEEL FOR PLATES. — INDENTING CYLINDERS. — MR. CHARLES WARREN'S COMMUNICATION TO THE SOCIETY OF ARTS. — OBSTRUCTIONS TO THE SUBSTITUTION OF STEEL FOR COPPER IN ENGRAVING. — AMAZING DURABILITY OF STEEL PLATES. — WARREN AND HUGHES'S METHOD OF PREPARING THE PLATES. — IMPORTANCE OF STEEL PLATES.

FOR several years past sheet steel has been used in large quantities instead of copperplates by the engravers. By this fortunate application of so durable and, it may be added, so economical a material, not only has a new field been discovered, admirably suited to yield in perfection the richest and finest graphic productions which the ingenuity of modern art can accomplish, but to do so through an amazingly numerous series of impressions, without perceptible deterioration. The art of engraving on iron or steel, for purposes of ornament, and even for printing in certain cases, is by no means a discovery of modern times; but the substitution of the latter material for copper, which has invited the superiority of the British burin to achievements hitherto unattempted by our artists, is entirely a modern practice.

In the year 1810, Mr. Dyer, an American merchant, residing in London, obtained a patent "for certain improvements in the construction and method of using plates and presses," &c., the principles of which were communicated to him by a foreigner residing abroad. This foreigner was Mr. Jacob Perkins, an ingenious artist of New England, and whose name subsequently became so extensively known in this country, in connection with roller-press printing from hardened steel plates. The plates used by Mr. Perkins were on the average about five eighths of an inch thick: they were either of steel, so tempered as to admit of the operation of the graver, or, as was more generally the case, of steel decarbonated, so as to become very pure soft iron, in which case, after they had received the work on the surface, they were case-hardened by cementation.

The decarbonating process was performed by enclosing the plate of cast steel, properly shaped, in a cast-iron box or case, filled about the plate to the thickness of about an inch, with oxide of iron, or rusty iron filings. In this state the box is luted close, and placed in a regular fire, where it is kept at a red heat during from three to twelve days. Generally about nine days are sufficient to decarbonise a plate five eighths of an inch in thickness. When the engraving or etching has been executed, the plate is superficially converted into steel, by placing it in a box, as before, and surrounding it on all sides with a powder, made of equal parts of burned bones and the cinders of burned animal matter, such as old shoes, or leather. In this state the box with its contents, closely luted, must be exposed to a blood-red heat for three hours; after which it is taken out of the fire, and plunged perpendicularly edgewise into cold water (which has been previously boiled to throw off the air); by this means the plate becomes hardened, without the danger of warping or cracking. It is then tempered or let down, by brightening the under surface of the plate with a bit of stone; after which it is heated, by being placed upon a piece of hot iron, or melted lead, until the rubbed portion acquire a pale straw colour. For this purpose, however, the patentee expressed himself in favour of a bath of oil, heated to the temperature of 460°, or thereabouts, of Fahrenheit's scale. The plate being cooled in water, and polished on the surface, was ready for use.

A more material peculiarity in Mr. Perkins's invention, and one which does not seem to have been approached by any preceding artist, was the contrivance of what are called *indenting cylinders.* These are rollers, two or three inches in diameter, and made of steel decarbonised by the process before described, so as to be very soft. In this state they are made to roll backward and forward, under a powerful pressure, over the surface of one of the hardened plates, until all the figures letters, or indentations, are communicated with exquisite precision, in sharp relief upon the cylinder, which, being carefully hardened and tempered, becomes by this means fitted to communicate an impression to other plates, by an operation similar to that by which it was originally figured. It will be obvious that one advantage gained by this method must be the entire saving of the labour and expense of re-cutting, in every case, on different plates, ornaments, borders, emblematical designs, &c.; as these can now be impressed with little trouble on any number of plates, or in any part thereof, by the application of the cylinder. At first sight the performance of such an operation as the one now alluded to may appear difficult, if not impracticable; and, indeed, many persons, on its first announcement, were disposed to doubt or deny its possibility altogether. With a proper and powerful apparatus, however, this method of transferring engravings from plates to cylinders, and *vice versâ,* is every day performed with facility and success, not only in the production of Irish bank notes, labels, &c., but in works exhibiting very elaborate engraving.

In 1824 the large gold medal of the Society for the Encouragement of Arts and Manufactures was presented to Mr. Charles Warren, for the communication of a paper on improvements in the art of engraving on steel. The death of Mr. Warren in the interval between the adjudication of the medal and the day of annual distribution of rewards having prevented the Society from receiving such details as were expected from the inventor himself, the committee drew up a report on the subject, from which, along with details communicated by Mr. Phelps and others of Mr. Warren's personal friends, the account published in the Society's Transactions was compiled. From this authentic source most of the following particulars are derived.

Some of the earliest specimens of engraving on steel, for the purpose of printing, were produced by Albert Durer. There are four plates etched by this artist, impressions of which exist in the British Museum, which, in all books treating on the subject, are recorded as having been executed in steel; of these, one has the date 1510 inscribed on it. Since that time attempts have been made occasionally to employ steel instead of copper, as a material to engrave upon, but apparently with little success, on account, principally, of the great hardness of the material, which in a short time blunted and destroyed the tools which were made use of.

Steel, as is well known, exists commonly in two states, the elastic and the brittle, the former being considerably softer than the latter; of the elastic steel, a saw-blade may be considered as an example, and, in fact, pieces of saw-blade were the material upon which nearly all the earlier attempts have been made, of late years, to revive a practice which, if successful, offered so many advantages to the artist and to the public. Mr. Raimbach, a few years ago, executed an engraving on a block or thick plate of steel, but met with so many difficulties in the execution, that his experiment remained insulated, and produced no sensible effect on the art of engraving.

Mr. Warren, in his early youth, was much employed in engraving on metals for the use of calico-printers and gunsmiths; and the experience thus acquired induced him afterwards to turn his attention to the subject, with a view of applying it to the fine arts. I was suggested to him by Mr. Gill, one of the chairmen of the committee of mechanics, that the method employed by the artificers of Birmingham in the manufacture of ornamented snuffers and other articles of like description, is, to subject the cast steel, after having been rolled into sheets, to the process of decarbonisation, by means of which it is converted to a very pure soft iron; being then made into the required instrument, or other article, the ornamented work is engraved or impressed on the soft metallic surface; after which by cementation with the proper materials, it is case-hardened, or again converted, superficially, to steel, and thus rendered capable of acquiring the highest polish.

In the attempt, however, to apply this process to plates for the engraver's use, two opposite difficulties occurred: a plate of steel, of the same thickness as that of common copper-plate, when thoroughly decarbonised, and thus reduced to the state of very soft iron, yields readily to the graver and other tools, and, especially, is susceptible of the process of *knocking-up;* this consists in scraping out any error of the graving tool, and afterwards striking the underside of the plate with a punch and hammer, in order to raise the cavity to the general level, and thus allow the artist to take the error out without occasioning any unevenness of the engraved surface; it was found, however, that plates of the thinness requisite for this operation, and of the usual superficial dimensions, were very liable to warp in the last or re-carbonising process, and were thus incapable of giving perfect impressions. If, in order to avoid this disadvantage, blocks, or plates, three or four times the ordinary thickness, were made use of, the warping indeed was prevented, but at the same time the process of knocking-up became impracticable, and it was necessary, in order to remove any error or defective part, to grind out the surface, or to drill a hole from the under surface almost through the plate, and then, by forcing in a screw, to raise that part of the face which was immediately above it. This latter process, however, was so tedious and difficult, as exceedingly to detract from the advantage of substituting steel for copper.

In this state of things it became a very interesting object of enquiry, to ascertain how many impressions might be taken from a plate of soft or decarbonised steel; and it was found that such a plate, prepared according to Mr. Warren's process, was capable of affording several thousand copies, without undergoing any sensible wear. In proof of this, the committee of the Society of Arts, &c. state, that impressions were laid before them by Mr. Warren, from two plates of decarbonised steel executed by him, the one for an edition of Mackenzie's works, published by Cadell, the other for an edition of Beattie and Collins, published by Rivington. These plates exhibited, both in the landscape and in the figures, the most elaborate and delicate work; five thousand impressions had been taken from one, and four thousand from the other; and yet between one of the first and one of the last impressions it was impossible to perceive any difference.

If Mr. Warren had carried on his experiments alone, working by himself till he had brought his plan to perfection, it is probable that, at the period of his death, the evidence of the great importance of his discovery would by no means have been so complete as it actually was; and the result of his exertions might have been lost, to the great detriment of the profession, and of the fair fame of this eminent artist. But selfishness and secrecy in any thing which related to the improvement of the art to which he was attached formed no part of his character; and all his discoveries, both those relating to the preparation of his plates, as well as those which had reference to the engraving upon them, were unreservedly and gratuitously communicated. The consequence of this liberality was, that besides the plates of Mr. Warren's own engraving produced before the committee above mentioned, impressions of portraits and other subjects engraved on decarbonised steel were shown, demonstrating that 8000, 20,000, and even 25,000 impressions had been taken off steel plates, before their respective artists had used them for the production of their own proofs.

Mr. Warren's original process for decarbonising the steel plates consisted in procuring a box or case of iron, and covering the bottom of it with a mixture of iron turnings and pounded oyster-shells; on this a steel plate is laid; another bed of the mixture is then added, and so on alternately, till the box is full, taking care that a bed of the composition should form the upper as well as the lower layer. The box so charged was then placed in a furnace, and kept for several hours at the highest heat which it would bear without melting; after which, being allowed to cool gradually, the plates were found to be reduced, for the most part, to the state of soft decarbonised steel.

Mr. Hughes, a copper-plate maker, having been instructed by Mr. Warren in his process, and finding that the steel did not always turn out sufficiently and uniformly soft (particularly for the purpose of engravers in mezzotinto), imagined that those occasional defects were owing to a deficiency of heat in the cementing process; accordingly, he substituted a case or oven of refractory clay, for the cast-iron one, and then applying a considerably higher heat than the cast-iron box would have endured without melting, was enabled to obtain plates so soft that they might be bent over the knee.

The best methods adopted by Mr. Warren and subsequent artists, for cutting, laying on the etching ground, and biting-in of steel plates, although of the highest importance, need not be pointed out in this place; it may, however, be remarked, that as the use of acids enters so largely into the processes of modern engraving in general, so steel is a most favourable material for the developement of the efficient action of the menstruum usually employed. It may be acceptable information to some of the readers of these pages to be told, that modern ingenuity has not only applied aquafortis extensively in the partial execution of portraits and other subjects, but even for letter engraving, exclusive of all co-operation with the graving-tool. The writer has seen specimens of work done in this manner, the strokes of all the letters in which were so fine, square, and clear, that nothing short of the scrutiny of an experienced eye could have detected the method in which it had been executed.

"Concerning the great superiority of steel-plate over copper-plate, for all works that require a considerable number of impressions to be taken, there can exist no doubt: for though the use of the graver, and of the other tools, requires more time on steel than on copper, and though the process of re-biting has not yet been carried to the degree of perfection in the former that it has been in the latter, yet the texture of steel is such, as to admit of more delicate work than copper; and the finest and most elaborate exertions of the art, which on copper would soon wear, so as to reduce them to an indistinct smeary tint, appear to undergo scarcely any deterioration on steel; even the marks of the burnisher are still distinguishable after several thousand impressions.* Steel plates are now applied to a new, and, as it promises, a very important use when the process is more fully developed. Mr. Fox Talbot has introduced a process by which etchings are produced by the agency of the sun's rays. The steel plate is covered with a solution of isinglass which holds bichromate of potash dissolved. This, when dry, is exposed, with the object we desire to copy laid upon it, to the sunshine. The bichromate of potash is decomposed, and the chromic acid combining with the isinglass, renders it very insoluble. The plate is then placed in water, which removes all the soluble gelatine; this being effected, a solution of the *bichloride of platinum* is poured over it, and the steel plate is rapidly etched. Botanical specimens, feathers, lace, and all such objects, are thus beautifully copied.

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* The engraved titles of the volumes of this Cyclopædia are printed from steel plates. Although many thousand impressions are in every case taken, yet no copies exhibit marks of wear in the plates.

CHAP. XVIII.

GRINDING.

PICTURESQUE APPEARANCE OF OLD SHEFFIELD GRINDING ESTABLISHMENTS. — DESCRIPTION OF THE MACHINERY. — QUALITY AND SIZE OF GRINDING-STONES. — GLAZIER, LAP, BUFF, ETC. — VELOCITY OF THE STONES IN REVOLUTION. — LIABILITY OF STONES TO BREAK. — DANGERS ATTENDANT UPON BREAKAGE OF STONES. — CONTRIVANCES TO PREVENT ACCIDENTS. — PERNICIOUS EFFECTS OF DRY GRINDING. — ABRAHAM'S AND ELLIOT'S PRESERVATIVES.

In most articles of cutlery, the blades, after being hardened, are directly carried to the grinding-mill, or *wheel*, as the establishment is called, for the purpose of being ground. Before the introduction of steam power, the grinding establishments in the vicinity of Sheffield exhibited much of that simplicity of structure and arrangement of machinery which probably characterised them seven or eight hundred years ago; especially those seated on the picturesque banks of the Porter and the Rivelin, two principal feeders of the rivers Sheaf and Don, the "Abana and Pharpar" of the modern Damascus. These grinding wheels being, in most cases, situated beside a fall in the stream, for the convenience of working an overshot water-wheel, their roofs are frequently but little elevated above the superior level of the adjacent ground, or of a large dam, which is constructed to collect the water during the night in seasons of scarcity, as well as for the ordinary convenience of allowing it to flow into the pentrough with regularity when the machinery is in motion.

Internally, the building is divided into *hulls*, and these into *troughs*; the former consisting of one room, the latter comprising a single range of grinding accommodations, as indicated by the profile sketch, *fig.* 81., in which A represents a table-knife grinder's stone, which, when first put into the trough, is about four feet in diameter, and nine inches across the face. These stones, which are of a peculiar grit, and cut with great eagerness, are of a reddish colour: they are quarried at Wickersley, in Yorkshire, a short distance from the celebrated ruins of Roch Abbey. When, either from use or inequality of texture, the stone becomes more worn on one part than another, the prominency is reduced, and the whole surface of the stone chopped with cross lines to make it cut faster, by means of a hack hammer, *fig.* 82. The stone does not always run in water, but is kept sufficiently wet by constantly dipping the article being ground into a bucket of water standing beside the grinder. In the course of ten weeks a stone will be worn down to the diameter of twenty inches: a deep groove is then cut in the face by the application of a piece of pointed steel, to render more easy the operation of splitting it into two smaller stones, immediately fit for the scissor-grinder's

Fig. 81.

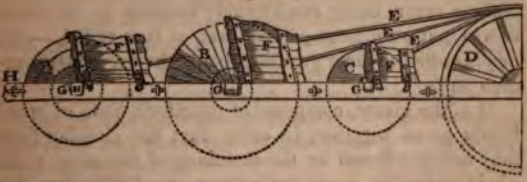


Fig. 82.

purpose. A table-knife grinder's stone can hardly be too large, the blades being mostly ground with a slight degree of convexity, or *rolled*, as the grinders term it; penknife and scissor blades, as they ought to be finished, the former within a single degree of perfect flatness, and the latter, a little hollowed, require a much smaller stone; while a razor, being considerably concave on the sides, is wrought on a mere *grindle coke*, as it is called,—the *ne plus ultra* of razor grinding, being the use of a "four-inch stone."

B is the glazer, composed of cuneiform radii of wood firmly glued together, in order that the circular form may not be affected by the shrinking of the pieces; the whole somewhat resembles a stout round table top, four feet in diameter, and two inches thick, except a boss in the centre, through which the axle passes. The surface is covered with stout leather, upon which, by means of glue, a coating of emery is laid. For razors, penknives, and scissors, a trundle is used, under the appellation of a *lap:* it is similar to this glazer in size and construction, but, instead of a surface of soft leather, it has a covering of soft metal—lead and tin, cast to the thickness of about an inch on the periphery; upon this flour emery is laid, and effectually detained by hatches or nicks chopped in the metal. For common work, these laps are sometimes made of wood, having the emery rubbed into interstices on the face.

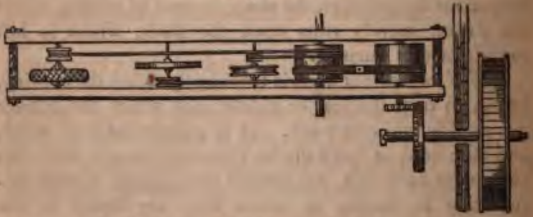
C is intended for a smaller and narrower stone of white grit, upon which the *bolster*, or that prominent part of a common table-knife blade which abuts upon the handle, is ground. Between the grindstone and the glazer the blades are passed over a fine dry stone: this intermediate process, which is called *whitening*, from the colour of the stone, is designed to correct the shape of the article, in those parts which could not be managed with sufficient nicety on the large wet stone, as well as to smooth the surface a degree. During this, as well as the preceding process, a brilliant stream of sparks is elicited from the steel in contact with the grit or the emery. This of itself is sufficient to show in what jeopardy the temper of any article is placed where the friction and consequent heat produce such a phenomenon.

Polishing or buffing, which generally follows lapping, is performed on a wheel similar to the glazer, only that, instead of having an emeried surface, it is covered with thick soft or *buff* leather, whence its name. It is dressed either with fine sand or very fine emery. For polishing, crocus marti of the finest sort is used. The velocity with which these polishers and buffs revolve is only about one twentieth of that required for the grindstone and the glazer. These buffs and glazers admit of being applied interchangeably in one another's place, by striking out the wooden nogs or wedges at G, in which the ends of the axle are inserted.

D is the drum or cylinder connected with the moving power, and over which are carried the leather bands E E E, which, passing thence round the pulleys on the axles of the stones and glazers, give motion to the whole. These glazers frequently revolve at a rate considerably exceeding a thousand feet per second: this amazing velocity is acquired by making the pulley of the glazer very small, so that its number of revolutions in any given time are computed according to the size and speed of the drum cylinder. To reduce this speed to the slowness proper for the polisher, the strap, instead of passing round the drum, merely runs upon the shaft, which is left round for this purpose.

F F F represents what is technically called the *horsing*, being, in fact, the seat or saddle upon which the grinder sits astride while at work. It is stoutly made of wood, and so placed as partially to cover the stone: over this seat, near each end, are carried two girders of iron terminating in hooks, by which they are linked to the beam H with massy chains. The necessity of these precautions is rendered awfully obvious to those who are aware of the many fatal accidents which have happened, and the danger consequent on the flying to pieces of a grindstone while revolving with such an amazing velocity. It not unfrequently happens, indeed, notwithstanding every precaution, that the grinders are killed or mutilated by the breaking of their stones, fragments of which have sometimes been known to drive the slates off the roof of the building. Stones are liable to fly on various accounts, either because they contain some fracture in their substance, by being allowed to become alternately wet and dry, but most frequently from too hard wedging about the axle, in which case the wood swelling with the moisture cracks the stone. In order to diminish the danger attendant on such accidents as much as possible, the main grinding-stone is always placed in front of the machinery. It has likewise now become a general practice to affix against each side of the stone a stout iron disc, or large circular plate, through which the axle passes: this contrivance tends very much to prevent the flying of the stone. Instead of the hard wedging of the axle in a very small hole, as in the common method, it is passed through these plates, which are fitted and bolted against the stone on each side, so as not only to secure it in this manner, but, by rendering central wedging unnecessary, and by removing the torsion to a distance from the middle, the liability to fly on this account is proportionately diminished. *Fig.* 83. presents a superficial view

Fig. 83.



of the machinery described above, including also the first drum, the spur, and water-wheels.

Besides the imminent danger to which the grinder is exposed from the breaking of stones, he has to do with a more insidious and not less fatal enemy, in the continual inhalation of minute particles of dust and ferruginous matter evolved from the stones, more especially during the process of what is called dry-grinding. The fork and needle grinders, therefore, who use no water upon their stones, and whose faces are constantly enveloped in this deleterious atmosphere, are most commonly the victims of this evil. The pernicious effects of the contact here alluded to, manifest themselves in a complaint known as "the grinders' asthma," the occurrence of which is so certain, and the progress so unrelenting, that in a body of men, consisting of several thousands, in a single town, very few of them arrive at the age of forty-five! Indeed, among the fork-grinders, it is very rare to meet with an individual thirty-six years old, especially since the grinding has been so generally transferred from the water to the steam wheels. In the former of these, the men worked in large lofty rooms, which did not contain more than six or eight stones, were open at the roof, often without windows, and generally with the large cog-wheel in the inside; thus, such a complete circulation of the air was effected, that the small quantity of dust raised from these few stones was soon carried away. Moreover, for several months during each summer, they could not work more than four or five hours a day, owing to a scarcity of water. With the steam engine a very important change has been introduced: the grinder now works in a small, low, glazed room, where there are ten or twelve stones, and the doors and windows kept almost constantly shut; hence, while a greater quantity of dust is evolved from so many stones, there is a proportionately less circulation of air to carry it away. Nor does the perpetual operation of the steam wheel admit any of those seasons of relaxation for the recovery of health which occurred under the old system.

To diminish or disarm this dreadful evil, various plans have been proposed; such as that the grinder should wear about his neck a suit of magnets; these, although they collected a sufficiency of the metallic particles to exhibit the danger in all its hideousness, did not affect the stone dust. To meet this remaining evil, a gauze cover for the mouth was added; the inconvenience, however, of these schemes, to say nothing of their inefficiency, formed a sufficient obstacle against their general adoption. It must be added, however, that much praise is due to Mr. J. H. Abraham, an intelligent Sheffield gentleman, for the numerous magnetical experiments which he undertook, in order to bring to perfection this method, and which certainly drew the attention of the public and scientific bodies in a particular manner. The Society of Arts awarded to Mr. Abraham a medal for his investigations on this subject.

The most successful apparatus for abating this danger has been invented by a person of the name of Elliott, whose ingenuity has likewise, very properly, been rewarded by the gold Vulcan medal of the Society of Arts. Mr. Elliott's contrivance consists simply of a long box or wooden chimney, placed opposite to and partially covering the stone in front, while the other extremity is carried through an aperture in the wall: in this arrangement it is found that such a current of air is excited by the mere revolution of the stone as to carry the dust evolved therefrom through this funnel, whence it may sometimes be seen issuing at the outside of the building. It might naturally be thought, as human life is generally so highly prized, that no inconvenience would be thought too great to be submitted to, when its preservation and protraction are the reward. But although these grinders have certain disease and premature death before them; yet, as these effects are not instant and obvious in their approach, not only are the troublesome wire masks and magnetical collars discarded, but the more simple and less inconvenient contrivance above described too often lost sight of! Persons employed in fire-gilding, and others who use mercury, are, it has been observed, compelled by the intolerable evil of sore mouths, &c. to take the necessary precautions against the effect of noxious fumes; but the grinders, stimulated by no such immediate intimations of an attack on the constitution hardly less fatal, seem to set remote consequences at defiance; as if they considered that, since the sum of life must be discounted so largely, it matters but little whether the amount be paid by instalments, or altogether at the last.

The manipulation necessary to produce the most effective cutting edge is of a very varied description. The broad flat surfaces of tools are traversed quickly to and fro upon the top of a grindstone, as a short period of rest would grind a hollow place of the same curvature as the edge of the stone. In the razor, on the other hand, the curvature is desirable. In grinding an ordinary plane-iron, the stone travels towards the operator, and the tool is applied about half-way up the stone from the axis. Carpenters' chisels are ground in the same manner as plane-irons. Almost every variety of tool requires a particular mode of treatment at the hands of the grinder. The peculiarities of holding the different tools — the various sizes and shapes of the faces of grindstones — cannot be detailed in the present treatise. Nor can we enter on the wide subject of sharpening tools upon the oilstone. On these subjects the reader desiring information is referred to those books which treat especially upon these subjects.

CHAP. XIX.

FILES.

ANTIQUITY AND MATERIAL OF FILES. — VALUE OF FILE-MAKER'S MARKS. — FORGING, STRIPPING, AND GRINDING OF FILES. — FILE-CUTTING. — MACHINERY FOR CUTTING FILES. — THEORY AND PRACTICE. — AMERICAN FILE-CUTTING MACHINE. — CUTTING MACHINES PARTIALLY APPLICABLE. — HARDENING OF FILES. — COMPOSITION USED. — TREATMENT OF THE ARTICLES AFTER GRINDING. — FRENCH AND ENGLISH FILES. — REPORT OF EXPERIMENTS MADE UPON FILES AT THE FRENCH LYCEUM.

THE manufacture of files, whatever may have been its origin or antiquity, is undoubtedly of first-rate importance, both as it regards the place which it holds among our sources of productive industry, and as furnishing an instrument of indispensable utility in the working of all metallic and many other solid substances. When or under what circumstances a tool now so common as the file was introduced into the workshop of the artificer, does not appear; its use, however, must have preceded every step in the progress of finishing articles composed of iron and steel in all cases where any intricacy of shape precluded the operation of grinding. That grinding, in the simple sense of sharpening a tool or a weapon by rubbing it upon a stone, must immediately have followed the invention of forging iron, may be safely inferred from the fact, that even in barbarous countries where the art of extracting iron from the ore is not yet known, the savages are in the habit of pointing and edging their darts and their knives, whether of bone or of flint, by working them with unwearied perseverance against the surface of some abrading material.

To this rude method of perfecting the form of early implements by simple attrition, the file in all probability succeeded; for, however common the revolving grindstone may have been for many centuries past, it certainly has no claims to be considered as of equal antiquity with the file. If we are to construe strictly a passage in the first book of Samuel (c. viii. v. 21.) it might be supposed that the Hebrews at all events were unacquainted with the useful process of grinding, for in performing their smiths' work, we are told, "they had a file for the mattocks, and for the coulters, and for the forks, and for the axes, and to sharpen the goads." In Homer's Odyssey, book viii. line 273—278., Vulcan is represented as manufacturing, by means of hammer and file, the wire for the net in which he afterwards entangled Mars and Venus. And almost every Latin school boy, whether given to versifying or not, will recollect the figurative allusion in the Horatian precept (*Art. Poet.*) to

> —— " the necessary toil
> Of slow correction and the painful file."

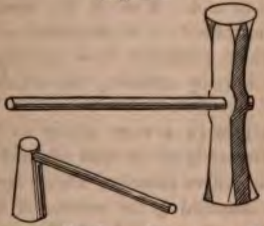
In our times, however, these ancient and diversified uses of the file have become obsolete: the makers of agricultural implements, and more especially the wire-drawers, have long since discarded such assistance: as to the metaphorical file, we must leave modern critics and poets to settle between them the question whether the materials with which they have to do are more tractable, or their instruments more perfect, than those of their predecessors; it is, at least, certain, that few "balladmongers" of our day would think of labouring for "nine long years" in furbishing their productions.

The material of files is invariably steel: but steel of very different degrees of value and excellence is wrought into articles, the weight of which, as well as the price, furnish strong incentives to deterioration. It must be obvious, nevertheless, that there are few descriptions of hardware in which the quality of the material is of more consequence, as constituting the base of utility. An axe, although entirely of iron, may by additional labour be made to do its duty on the whole; a saw, however inferior its substance, can, under most circumstances, by repeated renovations of its teeth, be used till it be worn out; and cutting instruments in general, by incessant whetting, rarely fail to be susceptible of bearing an edge more or less efficient: but for a bad file there is no remedy — no process of restoration. Let it be too soft, and immediately on application the whole toothed surface of the file is crushed down, and ceases to be of any use whatever for its intended purpose: if too hard, on the other hand, the teeth, so soon as they come into contact with the body to be acted upon, fly off with every stroke; the file thenceforward becoming, if not quite useless, certainly a coarse irregular rubber.

The general liability to these defects, which formerly attached to files manufactured cheap and for sale merely, gave a high value to certain marks well known in the trade both at home and abroad: hence instances of the falsification of these marks by surreptitious venders, have not been uncommon. On one occasion a vessel was blown by stress of weather into the port of Hull, having her cargo so damaged by the water getting into the hold, that it was deemed expedient to open out many of the packages, the contents of one of which were found to consist of a large quantity of German-made files, branded with the monogram of a celebrated English manufacturer! One of the most famous of these marks was that granted many years ago by the corporation of Sheffield to Daniel Brammall; and as an illustration of its value may be mentioned the fact, that in 1825 the rightful user obtained a verdict of 2000*l*. damages against a Birmingham file-maker for having struck it fraudulently on articles made by himself.

Steel intended to be wrought into files, whether after shearing or casting, is brought into bars under the tilt or by the rollers, as conveniently near to the ultimate shape as may be. When the files are flat square, the process of f[illegible] them out [illegible] bars is a very simple, thou[illegible] sorts, an exceedingly l[illegible] a maker and a striker, are required to draw out the larger files with hammers differing exceedingly in shape from those used by the blade-forgers. The smaller of these hammers, which is that used by the hearthman who holds the article under the operation, resembles a truncated cone, the wider end of which is the face, and is designed to cover a considerable portion of the surface of the file at each stroke, and while it expands, at the same time to level it: that wielded by the striker has a face at either end, and is of considerable size and weight: they are both represented in the engraving. Three-square and half round files, are usually forged in grooved bosses or dies fixed in the anvil; the making of the former shaped ones, however, has been much facilitated of late years, by the invention of a method of producing triangular rods of steel, by passing the material through grooved rollers—apparently a very obvious process, but one, as regards the article for files, by no means of easy attainment, in consequence of that perfection of surface which is indispensable. As the articles forged are generally of a considerable substance, and therefore while hot are very soft, they yield no rebound of the hammer, as is the case in making table-knife blades; this circumstance, especially in the large half rounds, causes the operations of the hammermen to be exceedingly laborious. In this process the file is formed, the tang drawn out, any loose pieces cut from the surface, and the mark impressed with a steel punch.

Fig. 84.



The next operation is that of lighting or annealing, in order that the steel may be so softened as to admit of being cut with sufficient ease by means of a chisel, when the teeth are to be raised. For this purpose, the files are either placed in an ordinary open fire, or, according to better practice, loosely piled upon the bottom of a brick oven; a fire is then kindled below and around the pile, upon which the heat is thrown with considerable intensity, and its effect accelerated or reduced by means of dampers. After the heat has been kept up about four and twenty hours, and the articles found to be sufficiently soft, every aperture is closed; the pile is smothered with ashes, and in this state the whole is allowed slowly to cool. This is the usual method: in cases, however, where it is desirable to preclude the slightest degree of oxidation, it is necessary to shut out the air altogether, by enclosing the articles in a box or coffer.

The file is now in a state either to be *stripped* or ground: the former is the method adopted in Lancashire and other places where grinding wheels are not common. It consists in smoothing the surface of the soft blank, by the application of a good hard file, used first across and then drawn along the surface of the article under preparation: it is an old and tiresome operation, but admits of being performed by those who are accustomed to the labour with considerable facility and complete success. The more general and ready course, however, is to prepare the surface of the file for cutting, upon the revolving grindstone, after the manner of cutlery in general. As the production of a level surface is the end especially sought by the grinder, the stone employed is mostly one of large circumference; and it has been made a question whether or not it be possible to obtain a surface so uniformly level throughout on the stone as by means of the file. As the highest degree of excellence claimed for both methods depends altogether upon the experience and the expertness of the workman, it is probable that, if the degree of perfection attainable by the stripping process have not been overrated, the inference of its practicable uniformity may have been: at all events, the expensiveness of the Lancashire operation precludes its adoption in the ordinary manufacture of large files.

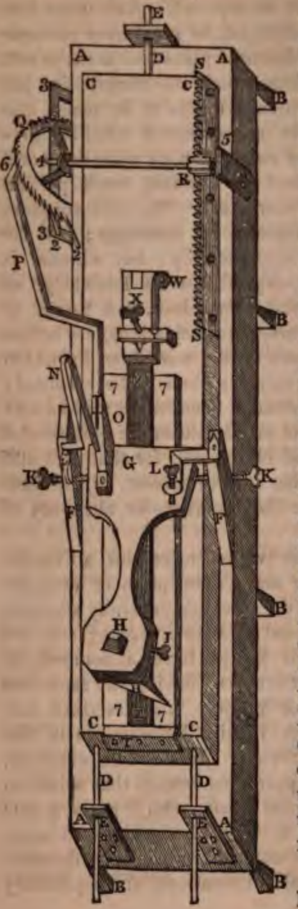
The files thus prepared are carried to the cutting shop, to undergo the process most material to their ultimate excellence. For this purpose, the workman, who sits up to his anvil, astride a board or saddle, places the file about to be cut upon a piece of lead, and by means of a strap, somewhat resembling a shoemaker's stirrup leather, passing over each end, he detains the article in its place with his feet. He then takes his hammer, and a smallish chisel, made of the best steel he can get, and very neatly ground and whetted, and commencing at the point, proceeds by a succession of smart strokes, to cut the surface across in parallel furrows, with the most singular dexterity, rapidity, and exactness; practice enabling him to maintain uniformity in depth and distance rather by feeling than by sight. In this state the file is what is called a *single-cut*, and is generally designed to be used upon brass, and the softer metals: for working iron and other materials, the single lines are closely cut over diagonally, and the file becomes a *cross-cut:* in other words, the surface, instead of presenting a succession of exactly parallel scrapers, offers a congeries of keen teeth. For the production of the cutting surface of files for wood, instead of a flat edge taking the whole breadth of the work, a triangular pointed chisel is used, which, on being struck into the steel, drives up little pointed portions, more or less numerous or elevated, as the instrument may be required for rougher or finer work. These, as well as some of the more deep and open cross-cuts, are called *rasps.*

From the apparent simplicity of the process, and the exact mechanical regularity of stroke exhibited by the workman, few reflecting individuals can overlook the operation for many minutes, without having suggested to their minds an idea of the practicability of substituting machinery for manual labour in the cutting of files. Nor is this the case with the unscientific observer merely;

mechanicians of first-rate ingenuity have both conceived and executed engines for that purpose. Among others may be mentioned Mr. Nicholson, who obtained a patent for complex apparatus, which he described at considerable length and with great minuteness in the Philosophical Journal, in which work he likewise refers to the labours of his predecessors in the same track of invention. The passage in which this ingenious practitioner has described the process of thought and experiment necessary to the successful demonstration of practical usefulness in machinery, is so relevant to the subject before us, that its perusal cannot fail to be gratifying: — "We will suppose," says the writer, "a very acute theorist, who is not himself a workman, nor in the habit of superintending the practical execution of machinery, to have conceived the notion of some new combination of the mechanical powers to produce a determinate effect; and, for the sake of perspicuity, let us take the example of a machine to cut files. His first conception will be very simple or abstracted. He knows that the notches in a file are cut with a chisel, driven by the blow of a hammer, by a man whose hands are employed in applying these instruments, while his foot is exerted in holding the file on an anvil by means of a strap. Hence he concludes, that it must be a very easy operation to fix the chisel on a machine, and cause it to rise and fall by a lever, while a tilting hammer of the proper size and figure gives the blow. But, as his attention becomes fixed, other demands arise, and the subject expands before him. The file must be supported upon a bed or mass of iron, of wood, of lead, or other material: it must be fixed, either by screws, or wedges, or weights, or some other effectual and ready contrivance: and the file itself, or else the chisel with its apparatus for striking, must be moved through equal determinate spaces during the interval between stroke and stroke, which may be done either by a ratchet-wheel or other escapement, or by a screw. He must examine all these objects, and his stock of means, in detail; fix upon such methods as he conceives to be the most deserving of preference; combine, organise, and arrange the whole in his mind; for which purpose solitude, darkness, and no small degree of mental effort will be required. And when this process is considerably advanced, he must have recourse to his drawing board. Measured plans and sections will then show him many things which his imagination before disregarded. New arrangements to be made, and unforeseen difficulties to be overcome, will infallibly present themselves. The first conception, or what the world calls the invention, required an infinitely small portion of the ability he must now exert. We will suppose, however, that he has completed his drawings; still he possesses the form of a machine only; but whether it shall answer his purpose depends on his knowledge of his materials. Stone, wood, brass, lead, iron forged or cast, and steel in all its various modifications, are before him; the general processes of the workshop, by which firmness, truth, and accuracy are alone to be obtained; and those methods of treatment, chemical as well as mechanical, which the several articles demand: — these and numberless other practical objects call for that skill and attention, which may either lead to success, or, by their deficiency, expose him to the ignorance or obstinacy of his workmen."

It is said that, more than two centuries back, a Frenchman published a drawing and a description of an apparatus for cutting files, on the principle generally adopted; several others have appeared in French works; and the mechanics of the United States have announced, at fewest, two or three contrivances, having the same object. A machine for this purpose was described and figured, several years ago, in the Transactions of the American Philosophical Society. The article is curious, as exhibiting one of the approaches toward that substitution of machinery for manual labour, which, in the article of cutting files, is held to be unattainable,—at least, which may be said to be unattained, while, notwithstanding the number of plausible inventions, there probably does not exist a single instance of their practical application.

Fig. 85.



A A A A, (*fig.* 85.) represents a bench, made of well seasoned oak, and the face of it planed very smooth. B B B B B, the feet of the bench, which should be substantial.

C C C C, the carriage on which the files are laid, which moves along the face of the bench parallel to its sides, and carries the files gradually under the edge of the cutter or chisel H H, while the teeth are cut: this carriage is made to move by a contrivance somewhat similar to that which carries the log against the saw of a saw-mill, as will be more particularly described. D D D are three iron rods, inserted into the ends of the carriage C C C C, and passing through holes in the studs E E E, which are screwed firmly against the ends of the bench, for the purpose of directing the course of the carriage.

F F are two upright pillars, mortised firmly into the bench, nearly equidistant from each end thereof near the edge, and directly opposite to each other.

G is the lever or arm which carries the cutter (fixed by the screw I), and works on the centres of two screws K K, which are fixed into the two pillars abovementioned, in a direction right across the bench. By tightening or loosening these screws, the arm which carries the chisel may be made to work more or less steadily.

L is the regulating screw, by means of which the files may be made coarser or finer; this screw works in a stud which is itself firmly screwed upon the top of the pillar F. The lower end of the screw L bears against the upper part of the arm G, and limits the height to which it can rise.

N is a steel spring, one end of which is screwed to the pillar F, and the other end presses against the pillar O, which is fixed upon the arm G; by its pressure, it forces the said arm upwards, until it meets with the regulating screw L.

P is an arm with a claw at one end, marked 6, the other end is fixed by a joint into the end of the stud or pillar O; and, by the motion of the arm G, is made to move the ratchet-wheel Q. This ratchet-wheel is fixed upon an axis, which carries a small trundle-head or pinion R on the opposite end; this works into the rack S S, which is firmly screwed against one side of the carriage: by means of this contrivance the carriage has motion communicated to it.

T is a clamp, for fastening one end of the file Z Z in the place or bed on which it is to be cut; V is another clamp or dog, at the opposite end, which works by a joint W, firmly fixed into the carriage.

Y is a bridge, likewise screwed into the carriage, through which the screw X passes, and presses with its lower end against the upper side of the clamp V; under which clamp the other end of the file Z Z is placed, and held firmly in its place while being cut.

7 7 7 7 is a bed of lead, which is let into a cavity formed in the body of the carriage, something broader

and longer than the largest sized files; the upper face of this bed of lead is formed variously, so as to fit the different kinds of files which may be required.

2 2 are catches which fit into the teeth of the ratchet-wheel Q, to prevent a recoil of its motion; 3 3 a bridge to support one end of the axis 4, of the ratchet-wheel; 5, a stud to support the other end of the axis.

When the file or files are laid in their place, the machine must be regulated, to cut them of the due degree of fineness, by means of the regulating screw L; which, by passing farther through the arm M, will make the files finer; and, *vice versâ*, by unscrewing it a little, will make them coarser.

"When the machine is thus adjusted, a blindman," says the original description, may cut a file with more exactness than can be done in the usual method with the keenest sight; for, by striking with a hammer on the head of the cutter or chisel H H, all the movements are set at work; and, by repeating the stroke with the hammer, the files on one side will at length be cut; they must then be turned, and the operation repeated for cutting the other side. It is needless to enlarge much on the utility or extent of this machine; for, on examination, it will appear to persons of but indifferent mechanical skill, that it may be made to work by water, or other power, as readily as by hand; to cut coarse or fine, large or small files, or any number at a time; but it may be more particularly useful for cutting very fine small files for watchmakers, as they may be executed by this machine with the greatest equality and nicety imaginable."

That the machine just described would cut common files successfully may appear likely enough to a mere theorist in the use and manufacture of those articles: to a *file-maker*, or a *file-user*, its inefficiency to produce good workmanship in the deeper cuts must be instantly apparent. Its applicability, or rather the applicability of some such principle, in the toothing of extremely fine-faced files, seems conceivable, as in such articles the *set* or direction of the teeth is a matter of much less importance than perfect equality of surface. The double dead cut files of the French exhibit such a beautiful uniformity of delineation when examined with a magnifier, that no doubt seems to be entertained, by many persons conversant with the art, of their being cut by machinery of some sort. But although the French are so successful in the production of this exquisitely delicate cutting, they are not equally so in the execution of the rougher sorts; and, consequently, English files are in high reputation in Paris, whither large quantities are regularly transmitted. The very perfection of cutting exhibited by some foreign files has been made a ground for their rejection by some persons. We knew an individual in Paris, who manufactured very fine, smooth watchmakers' files: these were cut in the common manner by his two daughters, but with such exquisite beauty and regularity, that although most highly valued by those who knew them, were by others regarded with suspicion, if not denounced altogether, as being machine-cut.

Some descriptions of rasps, especially such as are used upon wood and other soft substances, are left in their soft state after being cut, not only because little hardness is required, but mainly that they may be sharpened up with a file occasionally. Some sorts, too, have been made entirely of iron, and case-hardened. Mr. Martin says, "The carbonaceous matter may be readily obtained from any of the soft parts of animals, or from blood. For this purpose, however, the refuse of shoemakers and curriers is the most convenient. After the volatile parts have been distilled over, from an iron still, a bright shining coal is left behind, which, when reduced to powder, is fit to be mixed with the salt. Let about equal parts, by bulk, of this powder and muriate of soda be mixed together, and brought to the consistence of cream, by the addition of water. Or, mix the powdered carbon with a saturated solution of salt, till it become of the above consistence. Files which are intended to be very hard should be covered with this composition previously to hardening. By this method, files made of iron, which in itself is insusceptible of hardening, acquire a superficial hardness sufficient to answer the purposes of any file whatever. Files of this kind may be bent into any form, and, in consequence, are rendered useful to sculptors and die-sinkers." Mr. Gill, an individual exceedingly conversant with these matters, stated, in 1823, that "through the kindness of that eminent sculptor, the late Mr. James Smith, he was possessed of a half-round rasp, made in Italy, which fully possessed the admirable qualities of being as hard as usual, and yet admitting of being bent into any form of curvature. During the war such rasps became exceedingly scarce and dear."

In the hardening of files in general, success depends not merely upon the method adopted, but upon the rare union of care and experience in the workmen. Various compositions have, by different individuals, been adopted or recommended as most efficient to protect the toothed surface of the article against scaling, and, consequently, losing much of its sharpness when heated red-hot. The mixture used by some of the most celebrated manufacturers consists simply of the grounds of malt liquor, yeast, and common salt, crushed small: with this stuff the files are thickly smeared all over; they are then heated in a fire of clean cokes, to a sort of worm-red, in the course of which heating each file is occasionally withdrawn, and any bends or twists corrected by striking it with a small leaden hammer, across two pieces of the same metal placed upon a block at a convenient height for that purpose. The file, on being sufficiently heated, is then, if a square, or flat, or three square one, dipped perpendicularly in water up to the tang: by this process it generally acquires a set or bend of a greater or less degree of curvature. To restore the shape, the file is withdrawn from the tub before it is thoroughly cooled throughout, and being placed, the point under a staple and the middle across some competent support, the workman leans with his weight upon the opposite or tang end, meanwhile ladling the water with his hand upon the superior surface. By this means a degree of crookedness, amounting in some cases to almost a quarter of an inch in a foot, is effectually reduced; and what appears most remarkable in this manipulation, is, that the file in this only partially cooled but absolutely hardened state, never breaks under a stress more than fifty times sufficient to snap it when cold. This phenomenon of latent temper is more particularly observable in the hardening of half-round files, which, in order to counteract the superior contraction of the convex side during immersion, are previously bent to about the same extent in the opposite direction, and plunged horizontally; at the same time, often requiring a very violent effort of the workman to overcome the distortion.

Adjoining the hardening hearth is usually placed a bench, upon which the files are well scoured with a brush dipped into water and sand, to clean out whatever adheres to the cut surface; they are then passed through water in which quicklime has been dissolved, in order to neutralise the effect of any saline particles that might otherwise cause the steel to rust: they are, lastly, after having been completely dried before the fire, brushed over with oil. These courses of scouring, washing, and oiling are generally performed by women.

A good file is, in most cases, so brittle as to be extremely liable to break if suffered to fall upon a hard floor: workmen, however, too often find that, besides the danger of breakage from this and like accidents, the instrument will not unfrequently snap asunder by the tang, in consequence, principally, of the reduced substance of the latter. To remedy this defect, some of the best makers temper the tang end of the file by dipping it in a bath of molten lead.

Files, it may be remarked, are not only an article of vast consumption in our home manufactories, but likewise of heavy export,—literally *heavy*, indeed, for it is remarked that hardly any description of metal goods, not even excepting large anvils, admit of being packed in casks with such ponderous compactness as the larger sort of square files. Before the revolution, France was mainly indebted to this country for her best working files; and many English firms dealt directly with the Parisian shopkeepers, though in general the merchants were the factors. The war, however, by interrupting the commercial intercourse, and stimulating the mechanical rivalry of the two nations, compelled our ingenious neighbours to put their own artisans to the test: a natural, perhaps a useful result of hostile,rivalry, under such circumstances, must be, to beget a prejudice in favour of native productions, not likely to allow those under its influence to weigh with scrupulous accuracy the merits of foreign competitors.

Viewing the matter in the above light, it will not be uninstructive to peruse the subjoined detail of experiments made upon the files of both countries: it was translated from the Register of the French Lyceum, in the Repertory of Arts, 1801. Besides the importance of the result, there is a raciness of the bombast about it, which, at this distance of time, and under the present circumstances of the two nations, must render it amusing as well as admonitory. It is the opinion of Mr. Gill, that the celebrated files made by Raoul of Paris, and which, it is said, would really act upon or abrade English ones, as mentioned below, owe their hardness to being dipped in the following composition:— Two pounds of mutton suet, *not rendered*, but only chopped small; two pounds of hogs' lard; two ounces of white arsenic, powdered. These, being put into an iron vessel, with a cover fitted to it, must be boiled, until a handful of *mouse-ear* (*Hieracium Pilosella*), fresh gathered, and which had been put into the mixture at first, shall become crisp, and float on the surface of the liquor; a proof that all moisture is driven off. This operation, as well as that of quenching any article in it, in order to harden it, must be performed under the hood of a smith's forge-hearth, so as to carry off as much as possible the noxious arsenical fumes which arise; and the operator ought also to cover his mouth and nostrils to prevent his inhaling them.

The following is the Lyceum Report alluded to:—

"France has long been furnished with files by the English. The superiority and beauty of the English files were universally acknowledged, and we consumed annually to the value of several millions of livres

"Citizen Raoul, a French artist, desirous of procuring to his country the same superiority in this manufacture which it already possessed in many others, has succeeded in manufacturing more beautiful and better files than those with which England has hitherto exclusively furnished us.

"Comparative trials have already been made and repeated. The most eminent artists have given their opinion in favour of the files of citizen Raoul: and the Lyceum adjudged an honorary crown to him on the 10th Thermidor, year 8, upon the report of its commissaries, who had verified this discovery.

"It is well known that, even amongst the best English files, it is difficult to make a selection of any number that shall prove all of equal quality; whereas those of citizen Raoul, on the contrary, have been found to be all of uniform goodness.

"The Lyceum of Arts, one of the principal objects of whose institution was to give publicity to national discoveries, conceived that a sure means of producing an universal conviction of the superiority of citizen Raoul's files would be to call upon all artists, amateurs, and all the directors of large manufactories, to make a comparison of them.

"The Lyceum, therefore, invited all persons who interest themselves in the progress of the arts and the honours of the French nation, to bring the best English files which they possessed, and to put them in competition with files of the same grain manufactured by citizen Raoul.

"The competition took place on the fourth complementary day of the year 9.

"Citizen Mulot, ex-president, in the chair, and in the presence of citizen Gillet Lomont, commissioner appointed by the government.

"Citizen Balthazard, junior, watchmaker, presents a file, which is recognised by the company to be an English one, and marked T; it is a smooth of four inches. Citizen Bourdies, watchmaker, presents another, marked B. T. Bramall.

"A citizen, who had travelled in England, and been conversant in the English manufactories, comes forward to examine these files, which he recognises to be really English.

"*Experiment* I.—The grain of the file presented by citizen Balthazard, junior, is examined, and matched with one of citizen Raoul's files: some of the artists present observe that the grain of the latter is rather coarser, which gives the English file the advantage in the proof. Citizen Meyer, watchmaker, makes the experiment; the English file whitens (*blanchit*). Citizen Balthazard himself makes the same experiment upon both sides, both of his own file and of that of Raoul, and the same effect is produced.

"A citizen requests that more experiments be made, in order that no room may be left for doubt; possibly, he says, it might otherwise be suspected that the English file has not been tempered. Several other citizens observed that such a fact could not exist, as the file had filed effectively, and only whitened, which could only happen in consequence of its having been tempered.

"*Experiment* II.—The file of citizen Bourdier is brought to the trial; it is endeavoured to match its grain with some of Raoul's files, but none is found exactly similar to it.

"*Experiment* III.—Citizen Petit, an artist, belonging to the manufactory of arms at Versailles, presents a file marked T; it is endeavoured to match its grain: the choice having been made, citizen Petit acknowledges that his file is finer than that opposed by citizen Raoul. The assembly verifies and admits this fact; from whence it follows that the proof is made in a manner unfavourable to the file of citizen Raoul: citizen Petit tries the file himself, and acknowledges that the superiority is entirely on the side of the files of citizen Raoul, and that in a very striking manner. The experiment was made by commencing alternately with one of the sides of each of the files that were put to the proof.

"*Experiment* IV. — Citizen Provost presents seven files, which he says he has possessed fifteen years, and procured them directly from English manufactories. Their denomination and marks are as follows: —

1. A smooth, half inch round, 8 inches, marked G.
2. Smooth, 7 inches, marked B. Bramall.
3. Ditto, bastard, 6 inches, marked B*.
4. Ditto, round, 4 inches, marked B*.
5. Ditto, 3 square bastard, 3½ inches, marked B.*
6. Ditto, round smooth, 3 inches, marked I. P.
7. Ditto, flat smooth, 3 inches, marked T.

"*Experiment* V. — No. 1. is brought to the proof, and matched. Citizen Lenoir makes the experiment; the English file soon whitens, whilst that of citizen Raoul does not, and those who examine it declare it to be excellent.

"*Experiment* VI. — No. 2. is put in competition with a stronger file, which gives the advantage to the English file; it sustains the trial better than the preceding ones; however, that of citizen Raoul seems to deserve the preference: the assembly then demanded that these files should be tried upon a higher, tempered steel; the English file whitens, that of citizen Raoul completely resists in two trials.

"*Experiment* VII. — No. 4. is put to the proof by citizen l'Epine, watchmaker, Place des Victoires, at first upon steel moderately tempered; the files sustain the proof almost in an equal degree; that of citizen Raoul has the advantage: the experiment is repeated upon harder steel; the advantage still remains, and that in a more decided manner, with the file of citizen Raoul.

"*Experiment* VIII. — No. 3. is matched with a file of citizen Raoul, of a rather stronger grain; citizen Bourdier, watchmaker, of the Quai d'Horloge, makes the experiment: and having tried the experiment upon the first steel, without any decided advantage appearing on either side, he employed harder steel, upon which the English file No. 3. completely whitened, but that of citizen Raoul resisted in the most perfect manner.

"*Experiment* IX.—No. 5. being matched, the experiment is made by citizen Sallot, watchmaker, at first upon steel moderately tempered; upon the first stroke, the English file whitens; that of citizen Raoul resists completely.

"*Experiment* X.—No. 6. is matched in the same manner. Citizen Schey, manufacturer of cut steel, Fauxbourg St. Denis, makes the experiment, at first upon steel of the softest kind; no decided advantage results to either of the two files: he then repeats the experiment upon harder steel; the English file whitens at the first stroke, that of citizen Raoul resists.

"*Experiment* XI.—No. 7. Citizen Salneuve makes the experiment with this file, the best of those presented by C. Prevost. At the first stroke upon steel of moderate hardness the English file whitens; that of citizen Raoul resists completely, and to that degree that one cannot distinguish which of its three sides has been used for the experiment.

"*Experiment* XII.—Citizen Fouverel, watchmaker, Palais de Tribunal, presents an English file, marked B. T. Bramall, of eight inches; it yields upon steel of the softest quality, and whitens completely upon more highly tempered steel: it is observed that citizen Raoul's file alone resists both trials.

"As none of the persons present offered any more files for comparison, after having been repeatedly invited to do so by the president, the secretary having read the minutes of each experiment, the assembly adjourned."

CHAP. XX.

EDGE TOOLS.

ENUMERATION AND IMPORTANCE OF EDGE TOOLS IN GENERAL. — FALLACIOUS TESTS OF QUALITY. — MORTIFICATIONS CONSEQUENT ON THE PURCHASE OF INFERIOR IMPLEMENTS. — GOOD AND BAD HATCHETS. — AMERICAN AXES. — OLD NOTIONS ABOUT WELDING IRON AND STEEL. — WELDING DAILY PRACTISED. — DESCRIPTION OF MR. WALBY'S APPARATUS FOR HAMMERING TROWELS. — ROLLED STEEL TROWELS. — DESIRABLE QUALITIES IN EDGE TOOLS. — CAST-IRON PUNCHES.

UNDER the general designation of edge tools is comprehended, in the language of the trade, a considerable number of cutting instruments of the heavier kinds. Hatchets, adzes, chopping and drawing knives, plane irons, trowels, augers, and all sorts of chisels, are the principal articles; and from the mere enumeration of these, it will be at once seen that this class of tools must constitute no small or unimportant amount of those manufactures into which iron and steel unitedly enter. That the home consumption of the articles above named, and of others that class with them, must be immense, will become apparent on a moment's reflection; for upon the use of one or other, or all of them, depend nearly all those works and conveniences which distinguish civilised from savage man; and, in general, they are the very implements wielded by the pioneers of civilisation itself in every part of the world. As an item in the bills of lading with reference to foreign commerce, edge tools hold an equally prominent place; it is therefore obviously of the last importance that goods of such universal demand at home and abroad should obtain a due share of workman-like and mercantile attention. This they have undoubtedly received, though the result has not, it is to be feared, issued uniformly in favour of increased excellence.

The hatchet, as it is one of the most ancient, so it is likewise one of the most important, articles of the foregoing enumeration. It is an implement, too, the formation of which is so simple, and the use so unvarying, that it might be supposed the variations in its value would be few and immaterial; and yet, nothing can be wider than the difference between a good and a bad hatchet. In its formation at the anvil, the workmen, maker and striker, beat out a piece of iron into such a shape, that by turning it over a model, the eye or socket is made, and the welding effected; by this latter process, so much steel as is intended to constitute the cutting edge, is united with the head. It is then sent to the grinding wheel, where it receives upon the stone the necessary sharpening; and, when black varnished, it is ready for sale. All these processes, as already hinted, may be gone through in the most workmanlike manner, so that the axe may appear beautiful in form, and perfect in finish, and yet be worth little or nothing when it comes to be used. If the iron and steel work pretty freely, the forger calls the materials good, and if the edge come smooth and bright from the stone, the grinder is perfectly satisfied: both these criteria, however, may indicate a very worthless, as well as a very excellent, instrument. After the preceding remarks, it is hardly necessary to say, in so many words, that the value of a hatchet depends much less upon perfection of workmanship than integrity of material. It is, therefore, of the very first consequence to a workman, either in the woods or in the carpenter's shop, that his tool should be of the requisite quality; at least, this is the case so far as appearance is concerned: bad welding, of course, is exceedingly to be deprecated. The best steel may, in some instances, be injured by negligence in the manufacture; but no care, on the other hand, can compensate for the innate worthlessness of that which is of the opposite denomination.

America has long been the chief foreign market for this description of hardware; and it were to have been wished that the manufacturers of Great Britain had never conceded, through a deterioration of the staple, those advantages which might otherwise much longer have withstood the most enterprising rivalry. It is assuredly a question, the discussion of which might perhaps not unprofitably exercise the ingenuity of political economists, how far, in wares affecting the national credit and emolument, an individual has a right to deprave the quality of an article to any extent, to enable him to sell it at a price correspondingly low; and, moreover, what, on the whole, society gains or loses, between a regulation which compulsorily maintains in the article a standard degree of goodness, thereby confining its use to such as can pay the regular price, and a state of things which presents the lowest possible terms to facilitate its universal acquisition? A carpenter buys a drawing-knife, which is a stout blade, edged in the middle, and handled at both ends; it is neatly formed, finely ground, warranted, and above all *exceedingly cheap*. He congratulates himself on his bargain; but he no sooner begins to apply it fairly to its work than he discovers that cheapness is its sole recommendation: it cuts, indeed, but so indifferently, that between the incessant use of the whetstone and the misery of slicing with a good-for-nothing tool lies his only alternative. But what shall he do to help himself? he has the knife, and, bad as it is, he must even make his best of it: and thus he pays in the loss of time and temper a price beyond all comparison higher in the end for the indifferent article than he would have had to pay at the first for a really good one. The following is by no means an uncommon case in America. A Kentucky man comes from his woody location to New York, to purchase a hatchet. He suits himself with one that is heavy enough, and handsome enough (though he cares little for its beauty), and *cheap* enough. On reaching home, he proceeds to fit it with a handle; in the performance of this operation, he drives the wood so forcibly into the eye, that the iron, which is rotten, as the workmen say, gives way, and the instrument is of course entirely spoiled. The iron, however, is rarely so bad as to burst in this manner; so that, in general, the axe is carried out into the forest and applied to its proper use. The woodman presently finds that the steel is so worthless, that the edge will not stand at all; it is either friable, and breaks away in small masses, or it is soft, and turns again with the stroke. This is by no means an imaginary case; or rather, it *was* not; for such articles have brought even reputable British marks into disrepute; and the Kentucky man will not purchase an imported hatchet at any price, if he can obtain an American one. These remarks are extorted under a strong feeling of regret; not that the manufacturers of the United States should have the spirit and wisdom to use good steel, which has been expensively refined, but that our own makers should be content to sacrifice on an inferior material their own reputation and the credit of their country. This evil is sufficiently palpable, when these useless commodities are sold, *bonâ fide* at a low price: how much is the mischief aggravated, when they are palmed upon the confiding purchaser as of first rate quality! Nor let it be supposed that the "Yankee hatchets," as they are called, consist in general merely of good stuff rudely managed; we have seen axes and other cutting instruments from an extensive manufactory in Connecticut, which were not only made of excellent materials, but were formed and finished with a degree of perfection that must have convinced any person in the least acquainted with such matters, that the maker of such tools had nothing to learn in his business, and little to fear from competition. It will be obvious that these remarks apply with more or less force to the other articles enumerated above.

In the manufacture of almost every description of edge tools, the art of uniting iron and steel, by the process called welding, has so long been practised, that it would not be easy to point out a period when it did not exist. All the old workmen, however, used only shear steel, which, however excellent, was exceedingly malleable; and for many years after the invention of cast steel, although it was in the greatest repute for the formation of small articles, or such as consisted of but one metal, it was generally supposed to be impossible to weld it, either to common steel or even to iron. And however the words "cast steel," which the Sheffield artists early began to stamp even upon low-priced wares, might seem to have encouraged an approach toward the opposite conclusion; still the assertion of so high an authority as bishop Watson, who remarks in his Chemical Essays that cast steel, at a welding heat, "runs away under the hammer like sand," was long regarded as the distinguishing dogma of the orthodox theory.

So slowly did the ancient notion yield to experience, or so little satisfactory was experience, even in the place most favourable for its exercise, that, about forty years ago, a Sheffield saw-maker attempted the introduction into the edge-tool business of a method of steeling articles, by pouring the metal, when in a fluid state, into a mould, into which had immediately before been inserted the iron part of the instrument heated to a welding state, by which means the iron and steel became incorporated, and would admit of being hammered, rolled, or slit, for edge-tool purposes, "as easily as rolled iron," said the inventor. It was superseded, however, by a better process, and has long been forgotten in practice.

In 1795, sir Thomas Frankland, bart., in a communication laid before the Royal Society, asserted the practicability of welding cast steel. A few experiments convinced him that, contrary to the general belief, cast-steel in a white heat and iron in a welding heat united completely. He does not deny that considerable nicety is required in giving a proper heat to the steel, because on applying it to the iron it receives an increase of heat, and will sometimes run on that increase, though it would have borne the hammer in the state in which it was taken from the fire. The steels on which the experiments of the ingenious baronet were made, were Walker's of Rotherham and Huntsman's of Attercliffe.

Mr. Joseph Collier, in an essay on iron and steel read before the Manchester Philosophical Society in 1798, denies the validity of the statement of sir Thomas Frankland, and contends that only soft cast steel, little better than common steel, will weld with iron, as had been asserted, and that pure steel will not; for that, at the heat described by sir Thomas, the best steel either melts, or will not bear the hammer. If by "best steel," and "pure steel," Mr. Collier meant, what, however, the terms themselves do not imply, steel that had been subjected to the highest degree of carbonisation, he may be allowed to have come near the fact, which is, that the less the bars are charged with carbonaceous matter during cementation, the more readily will the cast metal endure the process of welding; though, hard or soft, the best and purest steel is vastly more tractable than the common or inferior sorts.

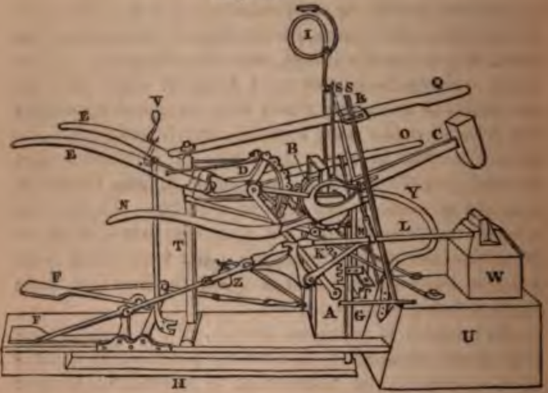
To bring these observations to bear on the practical question as to what really takes place in the workshops, it may be stated, that a considerable quantity of very excellent cast steel is now used in the manufacture of the lighter sorts of edge tools, and especially in plane-irons, and even in table knives, in which the disputed facility of welding it to iron is daily and successfully practised. The steel, however, used for these purposes, is not the very hardest that is made, namely, the kind required for the finest razor blades: *this* cannot be used without requiring more care than any result could justify. That it is *possible*, however, to weld steel, even of the highest carbonisation, the writer of this passage assured himself satisfactorily, by witnessing a clever workman unite by this process a bar of razor steel with a rod of Lowmoor iron: the suture where the two metals united was visible, but the junction was perfect; nor did there appear to be any symptoms of fracture in the harder metal, though they were drawn out to a considerable extent on the anvil.

Another article, to the production of which the spirit of modern improvement has applied the material of cast steel, is the mason's trowel, and other things of the like kind. Formerly trowels were made of iron, with the exception of the edges, which were composed by slitting the iron all round with a chisel, and inserting into the fissure a strip of steel, the whole of which was then welded, and the bit drawn out, so as to keep the better material as much to the edge as possible. Implements thus manufactured were not only soon worn, so as to be useless for cutting bricks, &c., but were much more liable to become rough and rusty on the face than those made entirely of steel.

As a maker of cast-steel trowels, Mr. Walby, of Goswell-street, obtained considerable reputation, by using a good material, and hammering to perfection; to give éclat to his attainment of this latter desideratum, he invented an ingenious skelper or tilt, to be wrought by hand on his own premises, and which was shown to his customers, and other curious individuals, as illustrative of his process. It is not to be supposed that all the trowels which he sold were indebted for their superiority to the operation of this machine; but as the symbol of a deserved celebrity, in this manufacture, a particular notice will be acceptable. The following cut represents the forge hammer alluded to, and for which the Society for the Encouragement of Arts, Manufactures, and Commerce, voted to Mr. Walby their silver medal, value forty guineas.

A is a block of oak, in which the hammer acts. B the wheel or nave, in which the hammer-handle C is fixed, also the chains which give motion to the hammer by the quadrant D. EE are two levers which work the quadrant D. FF are two pedals on which the man who works the machine treads alternately, holding the levers EE in his hands; when he treads on the right pedal F, he lifts the hand levers EE, which motion raises the hammer C; when he treads on the left pedal, he presses on the same levers, which motion lets fall the hammer. G is a rack which moves perpendicularly by the action of a strong wooden spring, H, placed in a trough underneath the centre of the machine; the rack is kept close to the quadrant K by a bridge containing a small friction roller. I an additional steel spring, fastened to the ceiling over the machine, in order to assist the wood spring H when fewer hands are at work. K is the quadrant contained in the centre of the block A under the nave B, which assists in raising or depressing the hammer by the alternate actions of the pedals FF. L is a lever fixed on the axis of the quadrant K, which at the time it depresses the rack G pulls upon the hammer-handle C by the chain

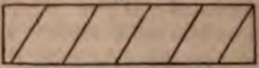
Fig. 86.



M, which adds to the power of the blow. NO are the two side levers, to be worked by two men, when more power is required. PP are two other pedals on which a man treads alternately, to give motion to the hammer, having an upright rod or chain to each pedal; one rod is connected from the right pedal P to the lever O, which raises the hammer; the other rod from the left pedal P is connected to the handle of the hammer C; when the man treads on the left pedal P he acts upon the hammer C, and by lifting the lever O with both hands at the same time, adds double power to the blow. Q is a wooden spring or stop, which prevents the hammer from rising too high, and accelerates the fall. R is a bridle which supports the wooden spring Q. SS are two iron standards, with holes in each, to raise or lower the said spring. T is a wooden standard, to support one end of the wooden spring Q. V is a steel tempered spring standard, to support the hammer whilst out of action; it also gives ease to the other spring, and prevents the heat of the anvil from softening the face of the hammer. U is a solid block of oak, on which the anvil stands. W the anvil, with a hollow dovetail at the top, for the reception of different faces, as the various kinds of work may require. X a steel face, dovetailed in the anvil. Y a steel spring, which lies beneath the hammer handle, but only touches it when the hammer falls: this spring, when the heated metal is laid upon the anvil, prevents the hammer from falling upon it with its full force, while in a soft state. It gives a recoil to the hammer, and permits the workman to modify or shorten the stroke of the hammer with quickness, ease, and regularity. Z is a weight hung on the arm of the quadrant K, in order to counteract the power of the hammer occasionally, when light work is to be forged.

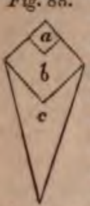
Cast-steel trowels have been, of late, plated or spread, with considerable success, by an ingenious application of the rolling process. A flat bar of steel, seven-sixteenths of an inch thick, and three inches wide, is cut into lozenge-shaped pieces, thus:—

Fig. 87.



One of these pieces is then taken and inserted between a pair of rollers, the uppermost of which has a small square hole sunk into its surface, five-tenths of an inch deep: into this cavity is compressed a small portion of the entire strength of the metal, *a* at the upper end of the annexed figure; the remainder, of the substance *b*, being spread out in the direction of the point *c*; thus producing a correctly shaped trowel of it. The thick portion, at *a*, is left to allow of the iron tang being welded thereto: and, in order to leave the plate stouter towards the handle, and thinner as it approaches the edges and the point, the surface of the upper roller is cut away, so as to mould the article with the precision required.

Fig. 88.



The edge-tool manufacturers are generally, likewise, the makers of chisels, engraving tools, and numerous other similar articles. These instruments not only require to be made out of cast-steel of the most perfect quality, but they ought to be treated, through every process, with the most exact attention; for it is of small advantage that the material be the best that can be produced, if the workman through whose hands it must pass be ignorant or negligent of any part of his duty. The qualities to be attained are hardness and toughness —qualities not seldom found in perfection *per se*, but rarely united to the extent desired in a single tool. If the article, after being carefully hardened, be afterwards too much reduced in the tempering, it will be found to be of little use when applied to cut steel or hard stone. It may, however, be re-heated, and again immersed: the error most to be guarded against is overheating; for this misfortune there is no remedy. It destroys, as the workmen say, the *nature* of the steel, which, instead of carrying an edge, crumbles away in minute particles on the slightest application. Horne, an old writer on this subject, did indeed give directions for the restoration of steel that has been in this manner *burnt*, as it is termed; but a better knowledge of its properties has long since exploded the notion.

Mr. Gill mentions that Mr. Stancliffe, a mathematical instrument maker, formerly employed by the celebrated Ramsden, adopted the following method in preparing steel articles in which great nicety was required:—after shaping the tool, and condensing it by hammering, he carefully heated the point and quenched it: he then, with the edge of a file, made trial, by filing along from the soft and unhardened part, to that part of it where it became hard, and formed his cutting part or edge, by grinding and whetting that part into shape. He was thus assured of the quality of his tool being the best that the steel he employed could possibly produce, nor did it require tempering as usual.

Although not, perhaps, properly belonging to edge-tools, it may be proper in this place to mention, on the authority last quoted, an ingenious method of obviating a defect which belongs even to the very best cast-steel articles, when used under certain circumstances. It is well known that, in making holes in red-hot iron articles, such, for instance, as wheel-tire, horse-shoes, &c., the hardened and tempered steel punches become softened from the effect of the heat; and, changing their shape, must be repaired from time to time. Mr. Peter Kerr, formerly an engineer at St. Pancras, having occasion to make many nail holes in the wheel-tire of artillery carriages and horse-shoes, and having experienced the above inconvenience in a very great degree, luckily bethought himself of substituting punches made of chilled cast-iron for those of steel, and which he found fully to answer the purpose, as they constantly retained their original hardness, notwithstanding they very frequently became red-hot in using.

As, however, chilled cast iron is not sufficiently tough to bear bending without breaking, he found it necessary to strengthen his punches, by surrounding and enclosing their stems in cast-iron holes, made of shapes corresponding with the stems, in properly shaped supports, and having their points only standing out a sufficient length for use.

CHAP. XXI.

SAWS.

FABULOUS ORIGIN OF SAWS. — EARLY FIGURES OF THESE INSTRUMENTS. — ESTABLISHMENT OF SAWING MACHINERY. — SAW MILLS IN ENGLAND. — MATERIAL OF SAWS. — SHAPING AND TOOTHING OF SAW BLADES. — HARDENING AND TEMPERING. — PLANISHING, OR SMITHING. — GRINDING AND GLAZING. — FINISHING. — OPINIONS RELATIVE TO THE TESTING OF SAWS. — INJURIOUS SYSTEM OF DEALING.

THE saw is undoubtedly, next to the axe, the instrument most effectual in the hands of man when the trees of the forest are to be appropriated to his convenience. The earliest and most obvious method of preparing timber for use would be to split the trunks with wedges, and afterwards to smooth and fashion the planks by means of the hatchet. This wasteful and slovenly process had allowedly one recommendation of no small importance in ages when the strength and management of timber were less perfectly understood than they are at present. In riving, the separation of the boards or spars necessarily followed the direction of the grain, and hence the strength of the material was secured at its maximum ratio, the disruption of fibre being much less easily effected in split than in sawn timber. It is equally certain that wood cut in this primitive manner must often be crooked and irregular; this, however, in many respects may be no disadvantage, but for some purposes a desideratum, as in shipbuilding: besides, the straightening of it would not always be impracticable. It is to the invention of the saw, however, that we owe the ease, economy, and regularity, with which the largest trees are separated into useful portions by modern industry.

The invention of the saw has been by the Greek mythologists attributed to Talus, Perdix, and Dædalus: into their respective claims Beckmann has entered at some length. The story conferring the honour upon the former of these worthies is thus told:—Talus was the son of Dædalus's sister, and was by his mother placed under the tuition of her brother, to be instructed in his art. Having once found the jaw-bone of a snake, he employed it to cut through a small piece of wood, and by these means was induced to form a like instrument of iron, that is, to make a saw. This invention so greatly facilitated his labour, that it excited the envy of his master, and instigated him to put Talus to death privately. The narrative proceeds, that being asked by some one, when he was burying the body, what he was depositing in the earth, he replied enigmatically, "A serpent." This suspicious answer discovered the murder; and thus, adds the historian (Diodorus), a snake was the cause of the invention, of the murder, and of its being found out. Perdix, we are told, did not employ for a saw the jaw-bone of a snake like Talus, but, according to Ovid and others, the back-bone of a fish. Some learning has been expended upon the terms used by the original writers; commentators, however, are divided between the back-bone and the jaw-bone of a fish. Beckmann is inclined to explain this difficulty by the bone which projects from the snout of the saw-fish, which is called by the Romans *serra*, and by the Greeks πριστης: that bone, he gravely observes, might not be altogether unfit for such an use, as the teeth are strongly united to the broad bone in the middle, and are capable of resisting a great force, but they are placed at rather too great a distance. An early writer, describing Cadomosto's voyage to Africa, does indeed state that the old inhabitants of Madeira really used this bone instead of a saw; a statement only one degree less ridiculous than that of the veracious Olaus Magnus, who states that the fish itself can with this instrument cut through the planking of a ship! The plain case appears to be simply this. The ancient poets and historians, finding in the structure of various animals parts somewhat resembling the saw in use among them, fancifully pursued the analogy, and, by a natural and easy fiction, transposing cause and effect, they referred to the origin what properly belonged to the illustration of an idea.

That the saws of the Grecian carpenters were pretty similar in form to those at present in use is satisfactorily inferred from a painting found at Herculaneum, in which two genii are represented at the end of a bench, consisting of a long table, each end of which rests upon two four-footed stools. The instrument in this representation resembles our frame saw: it consists of a square frame, having in the middle a blade or web, the teeth of which stand perpendicular to the plane of the frame. The arms too, in which the blade is fastened, have the same form as that which is at present given to them. The piece of wood which is to be sawn extends beyond the end of the bench, and one of the workmen appears standing and the other sitting on the ground. This is probably the most ancient authentic voucher for the early existence of an instrument resembling our common saw extant. Montfaucon has given figures of two ancient saws, though too imperfectly delineated to allow their peculiar formation to be distinguished. Palladius describes saws fastened to a handle, and Cicero, in his oration for Cluentius, incidentally mentions one with which an ingenious thief sawed out the bottom of a chest.

Since the fourth century, if not earlier, the working of large saws, with a reciprocating motion, by means of water power, has been more or less common in various parts of Europe, especially in Germany, Norway, and at a later period in this country. A succinct account of these early saw-mills will not be out of place here. According to Beckmann, there were saw-mills at Augsburg so early as 1322. When settlers were first sent out to the island of Madeira, which was discovered in 1420, not only were the various kinds of European fruits carried thither, but saw-mills were erected for the purpose of cutting into deals the many species of excellent timber with which the island abounded, and which were afterwards transported to Portugal. About the year 1427, the city of Breslau had a saw-mill which produced the yearly rent of three merks; and in 1490, the magistrates of Erfurt purchased a forest, in which they caused a saw-mill to be erected, and they rented another mill in the neighbourhood besides. In Norway, which is covered with forests, the first saw-mill was erected about the year 1530. This mode of manufacturing timber was called the "new art;" and because the exportation of deals was by means thereof much increased, this circumstance gave occasion to the deal tithe imposed by Christian III. in the year 1545. In 1555, the bishop of Ely, ambassador from Mary queen of England to the court of Rome, having seen a saw-mill in the neighbourhood of Lyons, the writer of his travels thought it worthy of a particular description, from which it appears that the motion of the blade was perpendicular; for, says the account, the wheel "being turned with the force of the water, hoisted *up and down* the saw."

Peter the Great introduced the saw into Russia. For this purpose policy was necessary. The czar, during his residence in England, and while employed as a carpenter in one of our dockyards, had, in all probability, both seen the advantages of the saw and used it with his own hands. On his return to St. Petersburgh, the capital of his dominions, among other things that attracted his attention, as requiring reform, was the practice of riving timber. Peter saw the necessity of introducing a more rational mode. Instead, however, of interdicting the old method, he imposed a duty upon all the split timber that was floated down the Neva, while sawn deals were exempted from the impost: by this course the rude practice of riving was soon superseded by the more effective operation of the saw wrought by machinery.

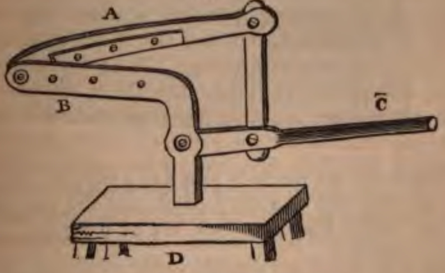
In the sixteenth century mills became general in which, by working several saws parallel to each other, a plank was at once cut into several deals. The Dutch have claimed the invention of this improvement, and a great number of saw-mills of this kind might formerly be seen at Saardam in Holland. The first mill, however, of this description is believed to have been erected in Sweden, in the year 1653; one of the wonders of which kingdom in this, was a mill having the water wheel twelve feet broad, and giving motion to seventy-two saws.

Saw-mills, on their introduction into England, had to encounter the fullest measure of opposition from that insane prejudice against all kinds of machinery which appears, as it were, to be hereditary in certain classes of workmen. The sawyers apprehended that they should be deprived of their labour and of their bread, and on this account their hostility was most determined. So early as the year 1663, we are told that, on account of the opposition of the workmen, it was found necessary to abandon a saw-mill which had been set up by a Dutchman in the neighbourhood of London; and about half a dozen years afterwards, when John Houghton laid before the nation the advantages of such a mill, he expressed at the same time his apprehension that it might excite the rage of the populace. What he dreaded it appears actually took place, in 1767 or 1768, when an opulent timber merchant, by the desire and with the approbation of the Society of Arts, caused a saw-mill, driven by wind, to be erected at Limehouse, under the direction of James Stansfield, who had learned in Holland the art of constructing and managing machinery of this kind. A mob assembled, and pulled the mill to pieces; but the damage was made good by the nation, and some of the rioters were punished. A new mill was, however, soon erected, and after it several others, which were suffered to work without molestation. In these mills, and those which rapidly succeeded them in different parts of the United Kingdom, the saws moved with a reciprocating motion, similar to their operation as we see them managed by two men at a pit in the ordinary manner. Of late years the efficiency of machinery for this purpose has been amazingly extended by the application of the circular saw, especially in the business of cutting boards, spars, brushwood, ships' blocks, veneers, and every other light description of work. The outrages that have been consequent on this further innovation on the old mode of hand-sawing are scarcely yet forgotten. These remarks are written almost within view of a circular saw-mill, erected on the site of one not long since burnt to the ground, without doubt by persons actuated by the motives above alluded to.

The common hand-saw, similar to that so universally in use among carpenters, has no doubt been known from a remote antiquity, in all probability, indeed, it presents the earliest form of the instrument. In that curious specimen of typography, the Nuremberg Chronicle, which made its appearance soon after the invention of printing, there occurs, amidst hundreds of other wood cuts, a rude picture of the building of the ark, in which two or three saws are introduced, differing but little from those at present in use with our joiners. The axes, on the other hand, delineated in the print, differ materially from those with which every one must be more or less acquainted. That the artist might intend them for antediluvian axes, may well enough be imagined by the reader, when told, that in a preceding picture of the expulsion of Adam and Eve from paradise, the gates of the garden of Eden are furnished with immense scroll hinges, like those sometimes seen on our old church doors.

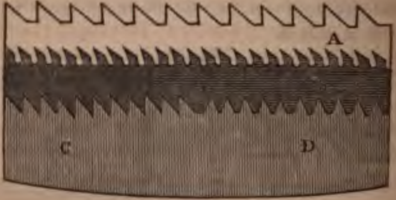
Saws are manufactured either of iron, which is hammer-hardened, or planished on an anvil, to give the requisite degree of stiffness and elasticity; or they are made of shear steel; or, lastly, of cast steel. The last named, of course, are the best, the most expensive, as well as the most durable articles: the only instruments, indeed, in which all the desirable qualities of a good tool of this kind are found to be combined. In preparing the material, when cast steel is used, the liquid metal is poured into a cast-iron mould, out of which the casting when cooled is taken, in the form of a short slab, about one and a half inch thick. This plate, after the fash has been removed from the angles, &c., is laminated by repeatedly heating and passing it between the rollers until it exhibits that degree of strength and extension which is required. If it be intended for a mill or pit saw, for which the whole piece may be necessary, it is merely pared into shape according to the prescribed pattern; if for smaller articles, it is cut up into such sizes as may be wanted. These operations are performed by means of an exceedingly stout pair of shears, which, in order that they may possess the greatest possible power, are formed with a lever handle, in the manner represented below. A B are the two iron mandibles with steel blades attached; C the lever by which the workman raises and depresses the upper blade; D the block upon which the shears are mounted.

Fig. 89.



When the web has been thus cut out to the proper size, and the edges made perfectly true, either by means of a file, or by holding them against the *flat* side of a large grinding stone, the article is ready to have the teeth cut upon the edge. The teeth are cut either singly or several at a stroke, by means of a steel cutter working vertically through a steel die, at a fly press, exactly similar to that already described under the head of "nail making." Of course, the size and form of the teeth are various, according to the purposes for which the article is designed. In an ordinary mill-saw, the teeth are right-angled triangles, measuring between their points respectively, about one inch and a quarter, and in depth about an inch. The teeth of an ordinary pit-saw consist of a succession of demi-lunettes, being the keenest form for cutting. The carpenter's hand-saw and most other common saws are toothed with small serratures, in form resembling those of the mill saw, with the exception of the intervals or spaces at the bottom of the toothing. The subjoined engraving represents a section of these three saws. A is the mill saw; B the pit saw; C the hand saw; D C the cross cutting saw, the line of the edge of which is somewhat convex.

Fig. 90.



When cut, the article is placed in a vice, and the teeth are severally filed to a sharp point, and the wiry edges, or fash, which may have been left by the punch, completely removed.

The next operations, hardening and tempering, upon the right performance of which so much of the excellence of steel instruments in general depends, require to be conducted with very particular attention in the article of saws. The hardening composition generally used by saw-makers consists of ingredients differing according to the fancy of the manufacturer; some use pale oil, others whale oil, while most add to these certain portions of rosin and tallow; some makers use other ingredients, which they affect to keep secret: the following recipe is recommended by Mr. Gill: —

Twenty gallons of spermaceti oil;
Twenty pounds of beef suet, rendered;
One gallon of neats' foot oil;
One pound of pitch;
Three pounds of black rosin.

These two last articles must be previously melted together, and then added to the other ingredients; when the whole must be heated in a proper iron vessel, with a close cover fitted to it, until the moisture is entirely evaporated, and the composition will take fire on a flaming body being presented to its surface; but which must be instantly extinguished again by putting on the cover of the vessel.

The saws, or plates as the workmen call them, which are intended to be hardened, after being heated to a cherry-red in a reverberating furnace or oven, are dropped edgewise into the liquid mixture, prepared as above described, and which is contained in an oblong vessel of a convenient size. When sufficiently cooled to admit of being handled, they are taken out of this bath, and are found to be extremely hard and brittle, and of course, smeared all over with the unctuous composition; a portion of this is scraped off by means of a piece of strong leather. In this state the article is passed backwards and forwards by means of a pair of tongs, over a clear coke fire, and as the liquid blazes off, it assumes the temper requisite. The web, immediately on its withdrawal from the fire, after this operation, retains a considerable degree of heat, of which prompt advantage is taken to correct the warping by smart blows given with a hammer on the hollow side, the other side resting on an anvil previously strewed with sand to prevent the article from slipping about.

The saw then undergoes another careful planishing or smithing by means of hammers, varying according to the strength or thickness of the plate, for the purpose of making it quite true, even, and of equable elasticity. The performance of this operation requires a degree of dexterity which must be the result of long experience;

the workman not only notices numerous inequalities not obvious to common observation; but, by giving to the web a vibratory motion, he perceives and corrects any defect in the tension of the whole with a precision akin to that with which a musician harmonises instrumental chords. Workmen of great celebrity have stated, that to secure the objects of this operation effectually, with the *fewest possible blows*. is the *ne plus ultra* of perfection.

Circular saws are manufactured from plates of sheet steel, and are toothed by means of a press and tools, the teeth being divided with great accuracy by means of a division-plate. The largest size saws are made in segments dovetailed together. The "set" of the saw consists in inclining the teeth at the particular angle known to be the best to facilitate the exit of the sawdust, and thereby allow the saw to operate more freely. Iron bars, shaftings, &c. are cut to length by a steel circular saw in its soft state, the iron to be cut being presented to the saw red-hot, the saw revolving at a prodigious rate, and kept cool by dipping its lower extremity into water. A bar, two inches in diameter, is cut through in a few seconds.

The next process is that of grinding. A saw-grinder runs the largest description of stones, these being not unfrequently as much as five, six, or even seven feet in diameter, and ten or twelve inches across the face; the web being so flexible an article, is, when applied to the stone, placed against a board, upon which the grinder presses, moving it about during the operation. When the saws are of the larger kinds, they are suspended at both ends from the top of the mill by cords, in order to prevent their ends from vibrating, and likewise to enable the grinder the better to manage the work. It is not easy to conceive the idea of muscular exertion, imminent danger, and peculiarity of attitude presented to the eye and the mind of an individual who, unaccustomed to such a spectacle, looks at a saw-grinder when at work, standing on tiptoes over a great grindstone revolving with a fearful rapidity; his arms outstretched towards the extremities of the board under which lies the saw, and pressing against it with his knees to keep it in the closest contact with the surface of the stone; his person and dress appearing at the same time as if they had been dipped in an ochre bed, present a picture of no common interest.

The operation of grinding again destroys, to a considerable extent, the flatness and straightness which the smithing had produced; the saw is therefore submitted to another process of hammering similar to the former. It is then passed over a small coke fire, until a slight degree of oxidation, amounting to a faint straw colour, appears on the surface; this restores the elasticity which had been lost by the grinding and hammering. The saw is now once more placed in the hands of the grinder, who draws it lightly and lengthwise over his stone to take out the marks of the hammering: after this it is passed over a smooth hard stone to take out any little inequalities which may have been produced by the small hard particles in the grit of the rough stone. When sufficiently smooth to take a polish, it is placed upon a buff or glazer, according to the market contemplated, or the fancy of the manufacturer. The saw buff is a round wheel, or trundle, covered with leather, attached by means of nails and glue: by occasionally wetting a portion of the same, and dipping it into fine emery, and passing it rapidly backwards and forwards upon the revolving wheel, the requisite polish is obtained. The glazer only differs from the buff in having its substance composed of numerous segments of hard wood, the ends uniformly presented to the surface, and upon which the saw is worked instead of upon the leather head: this is called "glazing on the hard-head." The only difference as regards the article is, that the latter mode produces a higher polish; but by *heating* the blade much more hammering is afterwards required. In both cases the saw is once more submitted to the hammer for the purpose of correcting any injury it may have received by the previous processes; but it is now termed *blocking*, and is performed by an experienced workman, who, with small polished hammers strikes the web upon the end of an upright post of hard wood. This process is expected to render the article quite perfect.

After this the saws are rubbed lengthwise, generally by women, with a piece of cork-wood and common emery, and then handed to the setter and sharpener, who places the teeth in an angular direction on the rounded edge of a small anvil, and with very light and suitably shaped hammers runs along the edge, striking every alternate tooth so as to bend it a little; he then turns the saw over and strikes the remaining teeth, in like manner, the contrary way. This is for the purpose of preventing the friction of the saws on the sides against the timber in working. It is then placed in a vice, the chaps of which are lined with lead to prevent vibration, and the teeth are all filed perfectly sharp. It is in the next place stiffened by passing it over a fire as before; after which the oxide is taken off by means of a little weak acid, and if it be an hand saw it is handled, when the hammerer finally looks over every article and corrects any slight imperfections which he may notice. The handle is then oiled, and the saw cleaned off, and wrapped up for the market.

Considerable difference of opinion exists between manufacturers as to the merit of a mode of testing saws which has long been considered as almost infallible by one class of judges, while another class have denounced it as fallacious. A principal in one of the most celebrated and extensive establishments in the trade favoured the compiler of this volume with the following observations on this disputed point. The gentleman referred to states, that the parties comprising the firm with which he [illegible] have long been aware that the [illegible] often regarded by a purchaser [illegible]roof of its quality; and they [illegible]h regret, seen the very best made goods seriously injured and sometimes spoiled by dealers submitting them to this very fallacious test.

It would require (continues this experienced sawmaker) a long treatise on the nature and properties of steel, with a tedious explanation of the numerous processes through which the article passes in the manufactory, fully to convince persons, unacquainted with these things, of the extent of the injury frequently done to saws by this practice. It may, however, be sufficient to state, that when saws, of whatever quality and temper, have been, as is usual, well rubbed with emery, they will not spring, and the makers always find it necessary to heat them until a shade of colouring becomes visible in order to restore this elasticity. Now it must be obvious that a quality of which a saw may be deprived merely by a little rubbing, and which heat will restore at so low a temper as barely to discolour a polished surface of the plate, cannot be an essential property (except for the purpose of retaining its shape); therefore the frequent bending of the blade will not only again destroy this elasticity, but, without great care, may also effectually spoil it as a tool. This cutler adds, that his firm has hesitated generally to publish this exposition, because its admission might give inferior makers an advantage over respectable houses, whose saws can better stand the equivocal test above mentioned. For assuredly this peculiar elasticity, to whatever extent it may safely be dispensed with in a saw made in the most perfect manner and of the best material, is certainly not discoverable in those articles, the quality and workmanship of which are inferior.

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